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(54) Title: LIQUID PHASE FLUORINATION (57) Abstract This invention pertains to a method for liquid phase fluorination for perfluorination of a wide variety of hydrogen-containing compounds.		

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LIQUID PHASE FLUORINATION

Background of the Invention

Hydrocarbons can be converted to fluorocarbons in two commercially viable ways. Electrochemical fluorination (ECF) is widely used to fluorinate materials which are soluble and stable in liquid hydrogen fluoride (HF). Of among the classes of materials prepared in this manner, perfluorotertiary amines and perfluorosulfonic acids are best suited for the technique giving yields generally in excess of 70%. Other classes of compounds such as carboxylic acids and their derivatives can be fluorinated electrochemically; however, the yields are usually low and have a tendency to decline rapidly as the number of carbons in the molecule is increased. In general, a very low yield (less than 25%) will be obtained for any perfluorinated carboxylic acid containing over 12 carbon atoms.

A second widely used process for preparing perfluorocarbons involves contacting a hydrocarbon, in the gaseous form, with cobalt trifluoride. This technique, although narrow in applicability, works

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well for low molecular weight hydrocarbons, especially polyaromatic compounds which are sufficiently volatile to allow vaporization. Examples of materials which can be fluorinated in this manner
5 include decalin, tetradecahydrophenanthrene, naphthalene, decane, dodecane, etc.

Russell et al. (U.S. Patent 3,897,502) describe a process whereby one or several fluorine atoms can be added to a partially fluorinated low molecular
10 weight hydrocarbon. The material to be treated is dissolved in an inert solvent through which dilute fluorine is bubbled at low temperatures (-10°C to -30°C). The resulting product is a partially fluorinated material which typically contains
15 several additional fluorine atoms. Scherer et al. (U.S. Patent 4,686,024) teach a method for perfluorinating low molecular weight partially fluorinated hydrocarbons. Highly fluorinated starting materials are slowly pumped into a fluorocarbon
20 solvent over a 3 to 5 day period. As the organic material is being delivered, a large excess of pure fluorine gas is bubbled through the solvent (typically a 5 to 8 fold excess). An ultraviolet lamp is used to activate the fluorine to produce the
25 products of interest. The yields reported generally range from 20% to 50% for materials which contain 3 to 5 hydrogens which must be replaced by fluorine. Callini et al. (European Patent Application 269,029) describe a fluorination process in which a hydro-
30 genated ether compound is reacted with F_2 diluted with an inert gas in a liquid phase, in the presence of a alkali metal fluoride.

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Summary of the Invention

This invention pertains to liquid phase fluorination for perfluorination of a wide variety of hydrogen-containing compounds. The fluorination is performed in a perhalogenated liquid medium, such as a perfluorocarbon medium, a perhalogenated chlorofluorocarbon medium or a perhalogenated chlorofluoroether. The hydrogen-containing compound is introduced into the medium while the medium is agitated so that the compound is dissolved or dispersed within the medium. Fluorine gas, diluted with an inert gas, is then introduced into the medium to fluorinate the hydrogen-containing compound. The fluorine is diluted so that it is below the flammable limits of the liquid medium (in fluorine). The fluorine is introduced in an amount in excess of the stoichiometric amount needed to replace all of the hydrogen atoms of the hydrogen-containing compound. The temperature is maintained above the melting point of the solvent, below the temperature at which fluorine reacts with the liquid and below the temperature in which fragmentation of the hydrogen-containing compound occurs. The fluorination is carried out in the absence of ultraviolet light and continued (as a batch or continuous process) until all the hydrogen-containing compound is introduced into the liquid medium and fluorinated.

It has been found, in accordance with the present invention, that a wide variety of hydrogen-containing compounds can be fluorinated using the

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liquid phase fluorination. The method of the invention can be used to prepare fluorinated products which can be prepared by ECF and cobalt trifluoride processes as well as products such as perfluoropolyethers, high molecular weight fluorocarbon diacids, and high molecular weight hydrocarbons which cannot be prepared by the existing fluorination technologies. The fluorinated products can be obtained typically in higher yield and in purer form than in other processes.

The mild conditions employed in the method of this invention make it possible to preserve chemical functionalities on a fluorinated molecule. For example, chlorinated hydrocarbons can be converted to polyfluorinated materials with essentially all of the chlorine being retained in original positions. Polyesters and acyl fluorides can be converted to perfluorocarbons with essentially complete retention of the ester functionality. Perfluoro-tertiary amines, sulfonic acids, sulfonic esters and ketones can all be prepared in high yield.

Brief Description of the Drawings

Figure 1 is a schematic representation of a liquid phase fluorination reactor.

Figure 2 is a schematic representation of another liquid phase fluorination reactor.

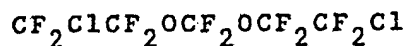
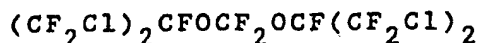
Detailed Description of the Invention

The perfluorination reactions are carried out in a liquid phase fluorination reactor. A suitable

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reactor is shown schematically in Figure 1. The reactor consists of a reaction vessel equipped with a means for agitating vigorously a liquid contained therein (a stirrer), a means of removing the heat (internal or external cooling coils, a constant temperature bath, etc.), a fluorine inlet, an inlet line for introducing the hydrogen-containing compound to be fluorinated, a gas outlet line, a condensor for condensing vaporized liquid from the reaction vessel and a liquid return line for returning condensed liquid back into the reaction vessel. Downstream from the reactor a hydrogen fluoride scrubber (such as a sodium fluoride-filled tube), instrumentation for measuring the fluorine concentration in the off gas (which can be done titrametrically, with an ion specific electrode, calorimetrically, etc.) and a fluorine scrubber (such as a tube filled with alumina, sulfur, etc.) are installed.

Liquid perhalogenated chlorofluorocarbons, chlorofluoroethers and perfluorocarbons serve as useful liquid phase medium in the fluorination reaction. Collectively, these compounds are referred to herein as the perhalogenated liquid fluorination medium. Examples of some such chlorofluoroethers are:



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When perfluorinating low molecular weight polyethers, it is preferable that the liquid fluorination medium be the same as the fluorination product of the reaction. This eliminates the need
5 to separate the fluorinated product from the liquid medium.

According to the method of the invention, the fluorination reaction is carried out by placing a perhalogenated liquid in the reactor, such as a
10 perfluorocarbon, a perhalogenated chlorofluorocarbon or a perhalogenated chlorofluoroether. For clarity, the following description pertains to 1,1,2-trichlorotrifluoroethane which is a useful solvent for most reactions; however, as pointed out above,
15 other perhalogenated chlorofluorocarbons or perfluorocarbons, such as Fluorinert FC-75 described in Example 70, may be used.

Before beginning the reaction, the reactor is purged of air, generally, by flushing the reactor
20 with inert gas such as nitrogen gas for approximately 30 minutes. The reactor temperature is adjusted to the desired temperature, i.e. a temperature high enough for the fluorination reaction to occur but low enough to prevent fragmentation of the
25 hydrogen-containing compound, usually between -40°C and $+150^{\circ}\text{C}$, preferably between -10°C and $+50^{\circ}\text{C}$. Similarly, the condensor is cooled to its operating temperature (typically -35°C). The hydrogen-containing material to be fluorinated is introduced
30 into the reactor at a controlled rate as fluorine gas and a diluent inert gas (e.g. nitrogen), or introduced therein. Preferably, the fluorine is

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bubbled through the vigorously agitated perhalogenated liquid fluorination medium but it may also be introduced into the vapor space of the reactor. The fluorine is introduced at a rate slightly above that required to theoretically replace all of the hydrogen atoms present on the molecule to be fluorinated (typically a 10% to 40% excess of fluorine is used). The fluorination reaction is carried out in the absence of ultraviolet light.

Upon completing the addition of the hydrogen-containing material, the fluorine concentration in the gas exit line typically increases sharply, denoting the end of the fluorination reaction. However, in the case of high molecular weight polymers (5,000 to 30,000 amu) and hydrocarbons which are either insoluble or sparingly soluble in the liquid, it is often beneficial to slowly meter into the reactor a small amount of a low molecular weight hydrocarbon such as benzene after adding the hydrogen-containing compound to be fluorinated to ensure perfluorination. The hydrocarbon reacts with the fluorine producing an abundance of fluorine radicals which are highly reactive and replace the last remaining hydrogen atoms on the product.

The hydrogen-containing compound to be fluorinated can be metered into the reactor neat if it has a sufficiently low viscosity (less than about 50 cst. at 100°F), or it may be diluted with a solvent. Normally, the solvent is the fluorination liquid. For example, if 1,1,2-trichlorotrifluoroethane is used as the liquid fluorination medium, the material

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to be fluorinated is typically diluted with 1,1,2-trichlorotrifluoroethane before being introduced into the reactor. With high molecular weight polymers which are often solids, the dilution becomes very important.

If the hydrogen-containing compound is insoluble in the perhalogenated liquid fluorination medium, it can still be fluorinated in high yield by forming an emulsion with the liquid fluorination medium. One convenient way of preparing such compounds involves preparing the emulsion continuously in situ as the fluorination reaction proceeds. For example, if 1,1,2-trichlorotrifluoroethane is used as the fluorination liquid, the hydrogen-containing compound is first diluted with a suitable solvent which has a high solvating power and at the same time will consume little if any of the fluorine. Chloroform, trichloroethene, trichloroethane, trifluoroacetic acid or trifluoroacetic anhydride can usually be used as the solvent. Upon dissolving the hydrogen-containing compound in the solvent, 1,1,2-trichlorotrifluoroethane is then added slowly until the reactant solution becomes cloudy, signifying that the hydrogen-containing compound is beginning to precipitate or become immiscible with the solvent mixture. The hydrogen-containing compound/1,1,2-trichlorotrifluoroethane/solvent mixture is then slowly pumped into the fluorination reactor in the usual manner, as previously described. As the solution contacts the perhalogenated liquid fluorination medium, a fine

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emulsion or precipitate is formed depending upon the nature of the hydrogen-containing compound. The solution, although heterogeneous, allows for fluorination as though it was homogeneous owing to the very small particle size of the suspended material.

5 The fluorine gas is diluted with an inert gas such as nitrogen. This is of particular importance if a fluorination medium such as 1,1,2-trichlorotrifluoroethane is used. It is imperative to keep the fluorine concentration low so that the perhalogenated liquid fluorination medium and fluorine in the vapor space do not form a flammable mixture.

10 The flammability limits of various solvents in a typical reaction, a fluorine concentration of 10 to 40% in 1,1,2-trichlorotrifluoroethane works well. If operating properly, the fluorine concentration in the exit gas will be between 2 and 4%.

15 The continuous addition reactor may be operated in a batch or continuous mode. If operating continuously, a small portion of the reactor contents and the liquid fluorination medium is returned to the reactor.

20 Sodium fluoride or other hydrogen fluoride scavengers, (see U.S. Patent 4,755,567) may be present in the solution to scavenge the by-product hydrogen fluoride. The preferred mode for carrying out the reaction for many polyethers is with a sufficient quantity of sodium fluoride being present

25 to complex with all of the hydrogen fluoride formed

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during the fluorination. When fluorinating ethers in the presence of sodium fluoride, improved yields are obtained while chain cleavage and rearrangements are minimized.

- 5 Polyethers containing sterically hindered oxygens and/or chlorine in the vicinity of the oxygen can be fluorinated in high yield without having a hydrogen fluoride scavenger present. Naturally, these reactions are more amenable to con-
10 tinuous processes than those reactions requiring a hydrogen fluoride scavenger.

The method of this invention is extremely versatile and allows fluorination of many different classes of hydrogen-containing materials, including
15 ethers and polyethers having 5 to 10,000 carbon atoms. Cyclic ethers having more than 10 carbon atoms can also be fluorinated by the methods of this invention. To illustrate this, the fluorination of several classes of compounds is described below.

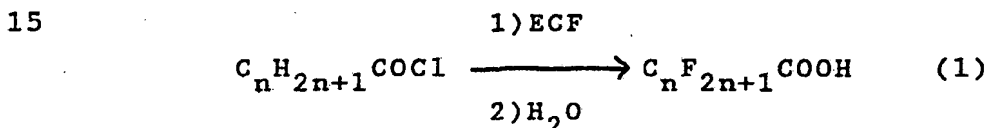
20 Production of Perfluorinated Acids and Their Derivatives.

Perfluorinated acids such as $C_7F_{15}COOH$ and their derivatives have received much attention through the last forty years principally because
25 many products of commercial value such as oil- and water-repellant finishes for textile and paper, stain-repellant finishes for leather, surfactants for a variety of applications and other commercial products are based on perfluorinated acids and th ir
30 derivatives. Perfluorinated acids are made primarily by two methods. The first method involves

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electrochemical fluorination (ECF) of acid derivatives to perfluorinated acid derivatives. The second main method involves the use of telomers made from perfluoroiodoalkanes and tetrafluoroethylene in multi-step routes. For a discussion of how perfluorinated acid derivatives are made see, for example, R.E. Banks, ed., Preparation, Properties and Industrial Applications of Organofluorine Compounds, Chapter 1, John Wiley & Sons, 1982.

In ECF of acid derivatives, the yield of perfluoro acid produced falls off rapidly with increasing chain length of the feed stock. The effect of molecular weight on the yield is best illustrated by the following reaction (1):



n=6, 16% yield; n=7, 10% yield; n=11, 0.5% yield. An important contributing factor for the low yields is the formation of cyclic perfluoropolyethers when n=3. For example, a major by-product of perfluoro-octanoic acid production is perfluoro-(2-n-butyl-tetrahydrofuran). Other by-products include tars and fragmentation products. The formation of by-products in ECF reactions of acid derivatives makes it difficult if not impossible to make materials such as some of the long chain diacids described in the examples which follow.

With the liquid phase fluorination techniques of this invention, it is possible to make a wide

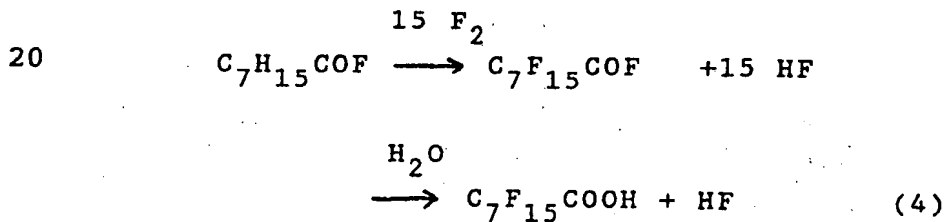
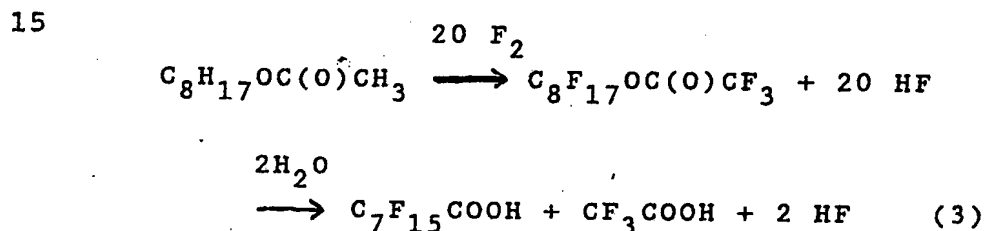
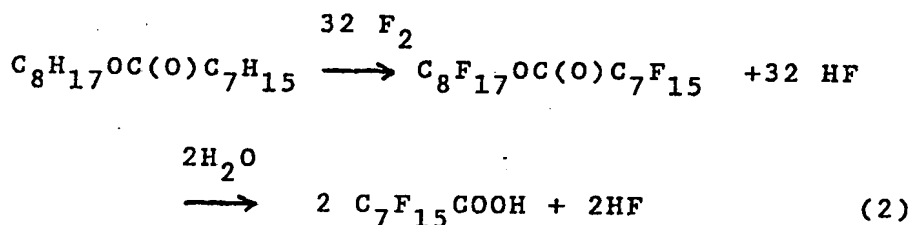
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variety of perfluorinated acids and acid derivatives in very high yields. In many cases there is practically no loss of functional groups and there are very few side reactions.

- 5 The hydrogen-containing starting material can be reacted with fluorine in a reactor such as the one just described and shown in the schematic of Figure 1. There are a variety of acid derivatives that can be reacted. Organic acids themselves are
10 generally not a good choice. For example, the fluorination of decanoic acid gives perfluorononane in high yield as the product decarboxylates during the fluorination. Although decanol can be used as a reactant to produce mainly perfluorodecanoic acid, a
15 potential by-product of this reaction is a hypo-fluoride so it may not be the reactant of choice. Acid halides work very well as organic reactants. Using decanoyl fluoride, perfluorodecanoic acid can be made in high yields. However, when decanoyl
20 chloride is used as the reactant, a considerable amount of chlorine substitution on the product results. With decanoyl chloride, the resulting product after hydrolysis contains a material where about 50% of the molecules have one or more
25 chlorines in the molecule (i.e. $C_9F_{18}ClCOOH$). Another disadvantage of using acid halides is that they must be handled under anhydrous conditions as they will easily hydrolyze to form acids which decarboxylate during the fluorination. However, the
30 use of acid fluorides might be the preferred feed-stock choice in a production facility as the least

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amount of elemental fluoride is needed. For laboratory-scale reactions, esters are probably the reactant of choice. With primary esters, both ends of the ester group are converted to perfluoro acids after fluorination followed by hydrolysis. For example, the hydrolysis of one mole of perfluoro-(octanoyl octanoate), gives two moles of perfluoro octanoic acid. Using octanoyl acetate, one mole of perfluorooctanoic acid and one mole of trifluoroacetic acid is made. As can be seen from the reactions below:

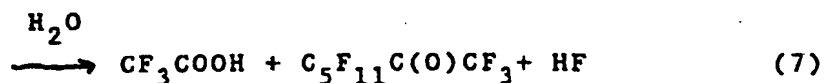
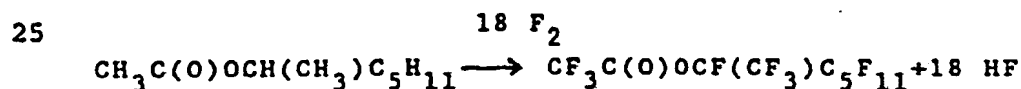
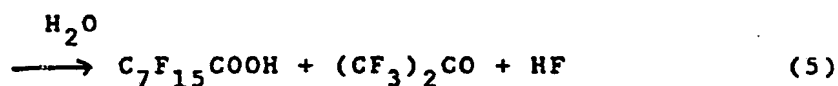
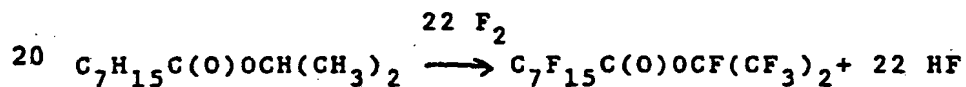


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slightly more fluorine is required to fluorinate an ester than the corresponding acid fluoride to make the same product. However, the hydrocarbon esters are stable in air and can be handled in glass

5 equipment. In a production facility, it may be more cost effective to use acid fluorides since the main cost of products would probably be associated with the cost of fluorine gas.

When secondary alcohols or esters of secondary
10 alcohols are reacted using this invention, the resulting product after hydrolysis is a perfluoro-ketone. For example, the hydrolysis of perfluoro-(isopropyl octanoate) yields perfluorooctanoic acid and hexafluoroacetone after hydrolysis. 2-Octanol
15 yields perfluoro-2-octanone and acetyl-2-octanoate yields trifluoroacetic acid and perfluoro-2-octanone after hydrolysis. These reactions are shown as follows:



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When tertiary alcohols are reacted according to this invention, tertiary alcohols are produced in low yields with mostly perfluoroalkanes being produced. However, esters of tertiary alcohols give
5 fair yields of tertiary perfluoro alcohols after hydrolysis.

There are many applications in the aerospace and related industries, in which, o-rings, gaskets and sealants are needed which can withstand high
10 temperatures while also exhibiting good low-temperature flexibility. The methylol-terminated prepolymers which can be made by reduction of perfluorocarbon diacids and described in several of the following examples are promising precursors for
15 such materials. For example, polyurethanes can be prepared by reacting hydroxyl-terminated fluorocarbons with aromatic diisocyanates. Similarly, useful binders can be prepared by reacting the methylol-terminated fluorocarbon with para-
20 formaldehyde.

Production of Perfluorinated Ethers

An important class of materials that can be produced using the liquid phase fluorination techniques of this invention are perfluoroethers and
25 polyethers. The production of perfluoropolyethers by ECF or cobalt trifluoride fluorination has not resulted in commercially viable processes due to extensive fragmentation reactions which usually occur. Methods have been developed for making
30 perfluoropolyethers by direct fluorination (see, for example, U.S. Patent 3,775,489). Liquid-phase

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fluorination provides a process capable of producing better quality (e.g., higher linearity) perfluoro-polyethers having higher yields.

5 Hydrocarbon ethers such as polyethers are more difficult to prepare by direct fluorination than other hydrocarbons due to their sensitivity to the by-product hydrogen fluoride generated in the process. Hydrogen fluoride has a tendency to cause acid cleavage of the ether linkages. The degree of
10 sensitivity varies greatly with the structure of the ether. Linear polyethers containing a low carbon to oxygen ratio are most reactive while polyethers containing some chlorine and fluorine substituents are remarkably stable in the presence of hydrogen
15 fluoride. In spite of this, virtually all ethers can be prepared by the method of this invention in excellent yields if provisions are taken to minimize the exposure of the ether to the hydrogen fluoride. A variety of techniques can be used to accomplish
20 this. For example, sodium fluoride can be charged into the reactor along with the fluorination liquid. The sodium fluoride slurry scavenges the hydrogen fluoride to give sodium bifluoride.

A slight modification of this approach which
25 works well involves placing sodium fluoride pellets in a second vessel through which the gaseous products of the reaction are passed. For this approach, the reactor shown in Figure 2 can be used. A gas pump is used to circulate the gases in the
30 reactor through the sodium fluoride bed (which removes the hydrogen fluoride) and then to reinject the gases, which contain unreacted fluorine, back

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into the reactor. By isolating the sodium fluoride from the product, the recovery of the product is greatly simplified and the process can be made continuous by employing several sodium fluoride beds which can alternately be regenerated by heating.

An alternate approach which gives satisfactory results involves using a perhalogenated liquid fluorination medium with a boiling point high enough to allow the fluorination reaction to be carried out at a sufficiently high temperature to allow the by-product hydrogen fluoride to be quickly removed from the reactor. This greatly facilitates the removal of hydrogen fluoride because the solubility of hydrogen fluoride in the liquid phase decreases with increasing temperature. Typically, a perhalogenated liquid fluorination medium having a boiling point near 100°C works well. Thus, it is often possible to prepare perfluoropolyethers in high yield without using a hydrogen fluoride scavenger.

A slight variation of this approach involves placing a sodium fluoride trap in the liquid return line between the condensor and the reactor. The majority of the hydrogen fluoride is swept from the reactor and is condensed in the condensor along with some of the fluorination liquid. The fluorination liquid is phase separated from the hydrogen fluoride and is returned to the reactor. By placing a sodium fluoride trap in the liquid return line, one can be certain that the liquid returning to the reactor is free of hydrogen fluoride.

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Production of Other Fluorochemicals

There are a wide variety of other fluorochemicals that can be made using this invention. Classes of materials that can be fluorinated include
5 alkanes, alkenes, aromatic hydrocarbons, sulfonic acid derivatives, amines, chlorinated hydrocarbons, carboxylic acid derivatives, ethers, formals, acetals, ketals, epoxides and others.

Perhalogenated acetals, ketals and formals are
10 described in U.S. Patent Application Serial No. 07/250,384, filed September 28, 1988 and Serial No. _____, Attorney's Docket No. EXF87-02A, filed concurrently herewith. Perhalogenation of epoxides is described in U.S. Patent Application
15 Serial No. 07/251,135, filed September 28, 1988 and Serial No. _____, Attorney's Docket No. EXF88-03A, filed concurrently herewith. The teachings of each of these applications are incorporated by reference herein.

20 Both large and small molecules can be reacted using this invention to yield products ranging from single compounds to polymers. Alkanes and alkenes are generally quite soluble in 1,1,2-trichlorotrifluoroethane and similar solvents so they can easily
25 be added either neat or in solution to the reactor. Materials such as perfluorokerosene are useful as mass markers in mass spectrometry. It is also possible to produce unique materials such as elastomeric perfluoroethylene-propylene copolymers using
30 this invention. Hydrocarbon ethylene-propylene copolymers can be produced with nearly any ratio of ethylene to propylene so it is possible to use this invention to produce perfluoroethylene-propylene copolymers with ethylene to propylene ratios of

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about one to one which are elastomeric. If one uses perfluoroethylene and perfluoropropylene monomers to produce perfluoroethylene-propylene copolymers, the difference in monomer reactivity limits the amount of hexafluoropropylene that can be incorporated in the polymer to a range such that the polymer is not elastomeric. Aromatic and polyaromatic hydrocarbons, such as phenanthrene or polystyrene, can also be reacted using this invention with the aromatic groups becoming saturated with fluorine as the hydrogens are being replaced with fluorine. Preferably, mono and polycyclic aromatic compounds will have 6 to 30 carbon atoms.

Perfluoroamines can be made using this invention as well. Although some of the yields are relatively low due to the tendency to form tars at some stage of the reaction, the addition of an acid such as trifluoroacetic acid to the hydrocarbon amine appears to improve the yield and the use of both a chlorofluorocarbon and liquid HF as the liquid phase in the reactor improves the yield even more.

Sulfonic acids and derivatives such as sulfonyl chlorides, sulfonyl fluorides and alkyl sulfonates can be converted in high yields to give perfluoroalkyl sulfonyl derivatives. Fluorocarbon sulfonyl derivatives offer many advantages over conventional hydrocarbon surfactants. They give lower surface tensions, are more stable; show surface activity in organic systems and exhibit both excellent water and oil repellancy. Although low

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molecular weight fluorocarbon sulfonic acid derivatives can be prepared in the electrochemical cell, the fluorination of hydrocarbon sulfonyl derivatives in perhalogenated liquid fluorination medium represents a superior means of preparing fluorocarbons having over six to eight carbons. Anionic surfactants based on fluorocarbon sulfonic acids function at increasingly lower concentrations as the molecular weight of the fluorocarbon chain in the surfactant increases.

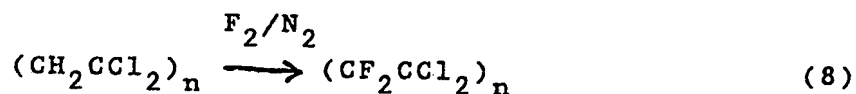
The invention described is particularly advantageous for preparing fluorocarbons containing two or more sulfonic acid derivatives. Unlike the electrochemical cell which gives very poor results when fluorinating molecules containing more than one sulfonic acid derivative, materials such as these can be prepared in good to moderate yields using the liquid phase fluorination reactor.

This invention also relates to a method of preparing chlorofluorocarbons by the reaction of chlorinated organics with fluorine gas. The reaction takes place at temperatures low enough to replace essentially all of the hydrogen atoms with fluorine while retaining all of the chlorine atoms present in the molecule. For example, telomers of polyvinyl chloride (PVC) can be fluorinated to give telomers of chlorotrifluoroethylene which contain chlorine on every other carbon. The regular structure results because vinyl chloride reacts strictly in a head-to-tail fashion. In contrast, telomers of chlorotrifluoroethylene prepared by

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polymerizing chlorotrifluoroethylene have a random structure and, as a result, are considerably less stable in air and in the presence of metal surfaces. The telomers prepared by fluorination of polyvinyl chloride are presently being contemplated as non-flammable hydraulic fluids.

Similarly, telomers of vinylidene chloride can be fluorinated to yield chlorofluorocarbons having a regular structure as shown by Equation (8). These materials are also reasonably stable and do not contain chlorine on adjacent carbon atoms.



The invention is further illustrated by the following non-limiting examples:

Example 1

A 10 liter stirred tank reactor was loaded with 5.0 liters 1,1,2-trichlorotrifluoroethane. Octanoyl octanoate (877g) was placed in an erlenmeyer flask and diluted to about 1900 ml with 1,1,2-trichlorotrifluoroethane. The nitrogen flow was set at 3400cc/min and the fluorine flow was set at 800cc/min. After three minutes, the octanoyl octanoate solution was added at a rate of 13.7 grams octanoyl octanoate per hour or 0.5 ml per minute. The reactor temperature was maintained at 0°C and the condenser temperature at -35°C. After all the octanoyl octanoate was added (64 hours), the nitrogen flow was reduced to 1500cc/min and the

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fluorine was reduced to 300cc/min. For 30 minutes these flows were maintained while 2 grams of benzene dissolved in 1,1,2-trichlorotrifluoroethane was added at a rate of 4 grams per hour of benzene.

5 After 30 minutes of benzene addition, the benzene flow was stopped. Fifteen minutes after the benzene flow was stopped, the fluorine was turned-off.

After purging with nitrogen, 300 grams technical grade methanol was added to the reactor. Approxi-

10 mately seven liters of material was dumped from the reactor which was distilled to yield 2430 grams that boiled at 155°C. Analysis of the product showed that much better than 99% of this fraction was $C_7F_{15}COOCH_3$ (83% yield). The major by-product of

15 the reaction was a dimer of perfluorooctanoic acid (490g).

Example 2

A 10 liter stirred tank reactor was loaded with 5.5 liters 1,1,2-trichlorotrifluoroethane. n-Decyl

20 trifluoroacetate (489g) was diluted with 1,1,2-trichlorotrifluoroethane to give a volume of 1600 ml. The nitrogen flow was set at 2000 cc/min and the fluorine was set at 470 cc/min, the reactor was held at -5°C. After four minutes the decyl trifluoro-

25 acetate solution was added at 38 ml per hour. Once all the decyl trifluoroacetate was delivered into the reactor, the fluorine flow was maintained for an additional 15 minutes to ensure perfluorination. After purging fifteen minutes with nitrogen, 200

30 grams of technical grade methanol was added to the

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reactor. The products were then distilled to give 903 grams of $C_9F_{19}COOCH_3$ (88.8% Yield) that contained about 0.5% of a material with one or more hydrogens in the fluorinated chain.

5 Example 3

A 10 liter stirred tank reactor was loaded with 5.0 liters 1,1,2-trichlorotrifluoroethane. 260 grams of decanoyl chloride was diluted with 1,1,2-trichlorotrifluoroethane to give 600 ml of
10 solution. The fluorine was set at 600cc/min with a nitrogen flow of 2400cc/min. The reactor temperature was held at 0°C. After five minutes the decanoyl chloride flow was set at 30ml/hr. When all of the decanoyl chloride was added (20 hours),
15 the fluorine flow was reduced to 300cc/min and the nitrogen to 1200cc/min and held under these conditions for 30 minutes. The fluorine was then turned off and the reactor was purged with nitrogen for 30 minutes after which time 120 grams of
20 methanol was added to the reactor. After distillation 310 grams of $C_9F_{19}COOCH_3$ was recovered (43% yield) with the major by-products being $C_9F_{18}ClCOOCH_3$, $C_9F_{17}Cl_2COOCH_3$, and C_9F_{20} .

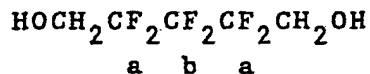
Example 4

25 A 10 liter stirred tank reactor was loaded with 5.7 liters 1,1,2-trichlorotrifluoroethane. 350 grams of 1,5-pentanediol diacetate was diluted with 1,1,2-trichlorotrifluoroethane to 700 ml. The nitrogen flow was set at 2000cc/min and the fluorine

-24-

flow was set at 570cc/min. After three minutes the flow of 1,5-pentanediol diacetate was set at 30ml/hr. The reactor temperature was held at -1°C during the reaction. After all of the pentanediol diacetate had been added (24 hours), the nitrogen flow was set at 1200cc/min with a fluorine flow of 300cc/min. Four grams of benzene was placed in 1,1,2-trichlorotrifluoroethane to give 30 ml and this was then pumped into the reactor at a rate of 30ml/hr for 45 minutes. The benzene flow was then stopped and the fluorine flow was terminated 15 minutes later. After purging with nitrogen, 300 grams of methanol was added to the reactor. After distillation, 457g (91.5% yield) of the dimethyl ester of 2,2,3,3,4,4-hexafluoropentane-1,5-dioic acid was obtained (b.p. 66-70°C at 14 torr). The dimethyl ester can be reduced with lithium aluminum hydride to give a hydroxy-terminated compound with a melt point of 75°C.

¹⁹F NMR (δ ppm vs CFC1₃): -122.6(a) and -126.5(b)



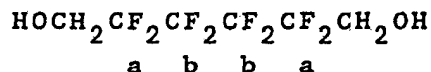
Example 5

A 10 liter stirred tank reactor was loaded with 5.0 liter 1,1,2-trichlorotrifluoroethane. 322 grams of hexanediol diacetate was placed in 1,1,2-trichlorotrifluoroethane to give a volume of 640 ml. The nitrogen flow was set at 1.8 liters per minute

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while the fluorine flow as set at 590cc/min. After three minutes, the flow of hexanediol diacetate was set at 28ml/hr. The reactor temperature was held at 0°C during the reaction. Once all of the hexanediol diacetate had been added (23 hours), the nitrogen flow was reduced to 1200cc/min and the fluorine flow was reduced to 300cc/min. Four grams of benzene was diluted to 30 ml with 1,1,2-trichlorotrifluoroethane and added at a rate of 30ml/hr for 30 minutes. Ten minutes after the benzene flow was stopped, the fluorine was turned off and the reactor purged with nitrogen. 300 grams of technical grade methanol was then added to the reactor to make the dimethyl ester of 2,2,3,3,4,4,5,5-octafluorohexane-1,6-dioic acid. The product was then distilled to give 474 grams of a fraction that had a boiling point of 108-110°C at 30 torr (93.5% yield). The product can be reduced with lithium aluminum hydride to give a hydroxy-terminated derivative with a melt point of 65-66°C.

¹⁹F NMR (δ ppm vs CFCl₃): -122.5(a) and -124.0(b)

Example 6

5.0 liters 1,1,2-trichlorotrifluoroethane were placed in a 10 liter stirred tank reactor. 291 grams of decanediol diacetate was diluted to 660 ml with 1,1,2-trichlorotrifluoroethane and placed in an erlenmeyer flask. The reactor temperature was held

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at +10°C during the reaction while the nitrogen flow was set a 2 liters/minute and the fluorine flow set at 630cc/min. After 3 minutes the decanediol diacetate solution was added at a rate of 29ml/hr.

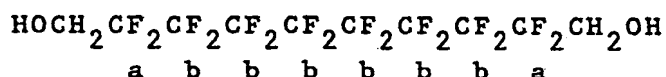
5 Upon completion of the addition (23 hours), the fluorine flow was reduced to 300cc/min and the nitrogen flow reduced to 1200cc/min. A solution of 4 grams benzene in 30 ml 1,1,2-trichlorotrifluoroethane was then added at a rate of 30ml/hr for 30

10 minutes. The fluorine flow was allowed to continue for an additional 15 minutes then stopped. After purging with nitrogen, 250 grams of methanol was added to the reactor to convert the hydrolytically unstable perfluoroester to the relatively stable

15 methyl esters. 402 grams of material (68.8% yield) was obtained having a boiling point of 102-113°C at .04 torr. The major impurity was about 150 grams left in the distillation flask that absorbed strongly in the infrared spectrum in the CF and

20 carbonyl regions.

¹⁹F NMR (δ ppm vs CFC1₃): -122.0(b) and -123.7(a)



Example 7

25 5.0 liters 1,1,2-trichlorotrifluoroethane were placed in a 10 liter stirred tank reactor. 307 grams dimethyl phthalate was diluted to 650ml and placed in an erlenmeyer flask. The reactor

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temperature was held at 0°C during the reaction. The nitrogen flow was set at 1800cc/min and the fluorine flow set at 460cc/min. After 3 minutes the dimethyl phthalate solution was added at a rate of 31ml/hour. Once all the dimethyl phthalate solution was added (21 hours), the nitrogen flow was reduced to 1200cc/min and the fluorine flow was reduced to 300cc/min. Four grams of benzene diluted to 30ml in 1,1,2-trichlorotrifluoroethane was then added to the reactor over a one hour period. The fluorine flow was continued for an additional 15 minutes. After the reactor was purged with nitrogen 280g methanol was added to the reactor. The products were then distilled at 52 torr to give 171g of a fraction that boiled below 120°C and 362g of a fraction that boiled at 120-128°C. The first fraction was about 90% pure $C_6F_{11}COOCH_3$ (31.8% yield) with the diacid as the major impurity. The second fraction was shown by gas chromatography to be about 98% pure $C_6F_{10}(COOCH_3)_2$ (60.2% yield) with an equal mixture there of the cis and trans isomers.

Example 8

In order to make perfluoro-2-octanone from an ester of 2-octanol, a trimethyl acetate ester of 2-octanol was used because the resulting perfluoro-ester is fairly resistant to hydrolysis. 5.0 liters 1,1,2-trichlorotrifluoroethane were placed in a 10 liter stirred tank reactor. 126.5 grams of the trimethyl acetate ester of 2-octanol was diluted to 700ml in 1,1,2-trichlorotrifluoroethane and placed

-28-

in an erlenmeyer flask. The reactor temperature was held at -8°C while the fluorine flow and nitrogen flows were set at 400 and 1500 cc/min, respectively. After three minutes the ester of 2-octanol was added at a rate of 39ml/hr. Upon completing the addition, the fluorine flow and other conditions were maintained for ten additional minutes after which time the fluorine flow was stopped and the reactor warmed. The product was transferred from the reactor in air with no attempt to do anything extraordinary to prevent hydrolysis. The solvent was removed from the sample by distillation and the bottoms were then transferred to a one liter nickel reactor where 10cc/min of F_2 and 40cc/min of nitrogen were bubbled through the liquid which was held at 110°C for four hours to remove any residual hydrogen left in the sample. After purging with nitrogen this sample was then distilled at atmospheric pressure to give 350 grams of a material that boiled at $181-182^{\circ}\text{C}$ (86.8% yield). The fluorinated product (265g) was hydrolyzed at elevated temperatures with 126g 1-octanol mixed with 17g sodium fluoride to give perfluoro-2-octanone which could be easily separated from the 1-octanol by distillation. The product distilled from the flask as formed (b.p. $100-150^{\circ}\text{C}$). Redistillation of the crude product at 105°C gave 155g (96% yield) of perfluoro-2-octanone.

Example 9

A 10 liter stirred tank reactor was loaded with 5.4 liters of 1,1,2-trichlorotrifluoroethane and

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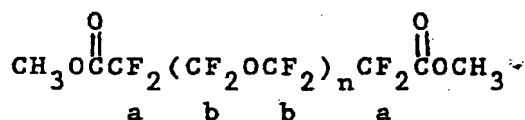
1415g of finely ground sodium fluoride powder. The reactor was positioned in a constant temperature bath which maintained a reactor temperature of -7°C . A condenser, which was placed downstream from the reactor, was used to condense and return to the reactor any liquid vapor which may be in the gas exit line. The condenser was maintained at -35°C . A mixture consisting of 328g of a poly(ethylene glycol) diacetate having an average molecular weight of 600, 320g of 1,1,2-trichlorotrifluoroethane and 113g of chloroform (used to solubilize the polyether in the 1,1,2-trichlorotrifluoroethane) was slowly metered into the fluorination reactor over a 26 hour period. Fluorine gas, diluted with nitrogen to give a concentration of 20%, was bubbled through the vigorously stirred fluorination liquid at a rate 10 to 15% higher than that required to theoretically replace all of the hydrogen on the hydrocarbon being pumped into the reactor. Following the reaction, the reactor was purged with several volumes of nitrogen to remove the unreacted fluorine gas. Next, 154g methanol was pumped into the reactor. The reactor warmed slightly as the perfluorodiester reacted with the methanol to give the hydrolytically more stable dimethyl ester. The product was filtered to remove the sodium fluoride and sodium bifluoride solids. The product (mw 1500), which was obtained in about 80% yield was separated from the 1,1,2-trichlorotrifluoroethane and methanol by distillation.

¹⁹F NMR of the product in chlorotrifluoromethane gave a small-triplet at -77.7 ppm (vs.

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CFC1₃) and a large singlet at -88.7 ppm corresponding to the terminal and interior difluoromethylene of perfluoropoly(ethylene glycol), respectively.

5



10

No definitive peak corresponding to a monofunctional or nonfunctional compound could be seen in the ¹⁹F NMR.

Example 10

A 252g sample of poly(ethylene glycol) having an average molecular weight of 1000 was mixed with 400g of 1,1,2-trichlorotrifluoroethane and 188g of trifluoroacetic acid to give a homogeneous solution which was slowly pumped into a 10 liter fluorination reactor containing 5.7 liters of 1,1,2-trichlorotrifluoroethane and 1150g of sodium fluoride powder. The reactor was maintained at 10°C as 20% fluorine was delivered at a rate sufficient to react with all of the organic being fed into the reactor. The reaction was complete in approximately 26 hours. Filtration of the product, followed by removal of the fluorination liquid gave 535g of perfluoropoly(ethylene oxide). Treatment of the fluid for several hours at 250°C with 30% fluorine converted the reactive terminal groups to perfluoroalkyl groups. The fluid was distilled into fractions having the following physical properties:

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Fraction		1	2	3
Property				
Boiling point range °C (mm Hg)		<200(100)	>200(100) < 245(10)	>245(10) <288(0.05)
5	% of total	13	40	36
10	Kinematic 20°C	3.32	13.2	33.9
	40°C	2.07	7.21	16.1
	Viscosity 60°C	1.43	4.25	9.05
	(cst.) 80°C	1.05	2.80	5.73
	95°C	0.85	2.09	4.19
	149°C	0.46	1.07	1.93
ASTM slope		0.934	0.725	0.681
Density (20°C, g/ml)		1.7484	1.7650	1.7883

(continued)

Fraction		4	5
Property			
Boiling point range °C (mm Hg)		>288(0.05) <343(0.05)	>343(0.05)
% of total		7	4
20	Kinematic 20°C	127.00	447.00
	40°C	51.9	173.00
	Viscosity 60°C	26.7	82.9
	(cst.) 80°C	15.5	44.9
	95°C	11.1	-
	149°C	4.27	11.4
ASTM slope		0.538	0.488
Density (20°C, g/ml)		1.8133	1.8234

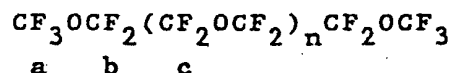
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^{19}F NMR of fraction #4 in CFCl_3 gave the following results:

(δ ppm vs CFCl_3)

-56.0 (t, 9.6Hz, a); -89.0 (s,c) and -91.0
5 (q, 9.6 Hz, b)



Anal. Calcd. for $\text{C}_2\text{F}_4\text{O}$: C, 20.69; F, 65.17.

Found: C, 20.77; F, 65.29

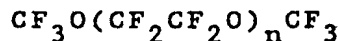
10 Example 11

In an experiment similar to Example 10, 252g of a poly(ethylene glycol) having an average molecular weight of 1540 was diluted with 500 ml 1,1,2-trichlorotrifluoroethane, 87g trifluoroacetic an-
15 hydride and 74g of trifluoroacetic acid. The homogeneous solution was pumped over a 28 hour period into a 10°C fluorination reactor containing 5.7 liters of 1,1,2-trichlorotrifluoroethane and 1150g of sodium fluoride powder. Following
20 filtration and distillation of the product, 398g of a perfluorinated fluid was recovered (60% yield) along with a small amount of elastomeric solids. The fluid had a composition identical to the fluid described in the previous example and a molecular
25 weight of 2,500 amu.

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Example 12

A perfluoropolyether elastomer was prepared by dissolving 146g of an 18,500 a.m.u poly(ethylene glycol) in 354g of chloroform containing 564g of 1,1,2-trichlorotrifluoroethane. The viscous solution was slowly pumped into a 10°C reactor containing 5 liters of 1,1,2-trichlorotrifluoroethane and 800g of sodium fluoride. Twenty percent fluorine, diluted with nitrogen, was metered into the reactor throughout the reaction which lasted approximately 28 hours. Following the reaction, the product was filtered to give a clear filtrate which contained 14.5g of a polymeric fluid (3.8%). The insoluble portion of the product consisted of sodium fluoride, sodium bifluoride and perfluoropoly-(ethylene oxide) solids (81% yield) having the following structure:



The solids were pressed into thin elastomeric sheets using a laboratory-size mill. The polymer remained elastic over a temperature range of -80°C to +360°C.

Example 13

Five hundred grams of poly(tetramethylene ether) glycol having an average molecular weight of 1000 were treated with a 50% molar excess of acetyl chloride to convert the hydroxyl end groups of the polymer to acetate groups. The acetylated polymer (288g) was mixed with 500 ml 1,1,2-trichlorotrifluoroethane and was slowly pumped into a 10 liter

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reactor containing 5 liters of 1,1,2-trichlorotri-
fluoroethane and 1400g of sodium fluoride powder.
The reactor temperature was maintained at 5°C while
20% fluorine was metered into the reactor at a rate
5 sufficient to react with the organic being
delivered. Following the reaction, the product was
filtered to remove the sodium fluoride and the
filtrate was concentrated to give 700g of a fluori-
nated oil (81% yield) which was treated for 12 hours
10 at 270°C with 30% fluorine to remove any remaining
hydrogens and to convert the terminal esters to
nonreactive perfluoroalkyl groups. Approximately
40% of the oil distilled between 200 and 300°C at
0.05 mm Hg. The average molecular weight by ^{19}F NMR
15 end group analysis was 3054. The fluid had a pour
point of -50°C.

Viscosity of
Perfluoropoly(tetramethylene ether) glycol

20	Temperature	Viscosity	Slope
	°C	(cst.)	ASTM #D341
	20	164.9	
	80	14.61	-0.654
	150	3.29	

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¹⁹F NMR data for
Perfluoropoly(tetramethylene ether) glycol

	Structure	δ (Multiplicity) ppm vs CFC1 ₃	J(F-F) Hz	Rel. Inten. %
5	CF ₃ O	-55.7 (t)	18.3	0.2
	CF ₃ CF ₂ CF ₂ O	-81.9 (t)	7.3	4.9
	OCF ₂ CF ₂ CF ₂ CF ₂ O	-83.3 (s)		42.6
	CF ₃ CF ₂ CF ₂ O	-84.3 (m)		3.3
	CF ₃ CF ₂ O	-87.3 (s)		0.8
10	CF ₃ CF ₂ O	-88.5 (p)		0.5
	OCF ₂ CF ₂ CF ₂ CF ₂ O	-125.7 (s)		42.6
	CF ₃ CF ₂ CF ₂ O	-130.0 (s)		3.3

Anal. Calcd. for CF₃CF₂CF₂O(CF₂CF₂CF₂CF₂O)_{12.5}-
CF₂CF₂CF₃:

15 C, 22.00; F, 70.92. Found: C, 21.87; F, 70.02

Example 14

Using the procedures outlined in Example 9, a solution consisting of 280g of poly(tetramethylene ether) glycol (terminal groups treated with acetyl chloride to give a diester) having an average molecular weight of 2000 and 550 ml of 1,1,2-trichlorotrifluoroethane was slowly metered, over a 32 hour period, into a 5°C fluorination reactor containing 5 liters of 1,1,2-trichlorotrifluoroethane and 1400g of sodium fluoride powder. Upon completing the reaction, the reactor was purged with several volumes of nitrogen to remove the unreacted

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fluorine gas. Methanol (150g) was added to the reactor. The reactor contents were filtered to give a clear filtrate which upon removal of the 1,1,2-trichlorotrifluoroethane and unreacted
5 methanol via a distillation gave a nearly quantitative yield of perfluoropoly(tetramethylene ether) dimethyl ester (mw 4250).

Example 15

Into a 500 cc stainless steel pressure vessel
10 were placed 250g 1,2-epoxybutane and 1g ferric chloride catalyst. The reactor was rocked in an 80°C oven for approximately 96 hours during which time the epoxide polymerized to give a high molecular weight semisolid. The polymer was
15 dissolved in 1 liter of 1,1,2-trichlorotrifluoroethane and pumped into a fluorination reactor using the procedures outlined in Example 9. The reactor, which contained 5 liters of 1,1,2-trichlorotrifluoroethane and 1250g sodium
20 fluoride powder, was held at 0°C with a constant temperature bath. Following the 22 hour reaction, 750g of fluid was recovered which was further fluorinated at 300°C with 30% fluorine for an additional 24 hours to give 660g of fluid (88% yield). Ap-
25 proximately 220g of fluid distilled between 200 and 300°C at reduced pressure (0.05 mm Hg) with approximately equal amounts boiling below and above that range. The average molecular weight of the mid-fraction was 1850 (by ¹⁹F NMR end group
30 analysis). The fluid had a pour point of -9°C.

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Viscosity Of Perfluoropoly(1,2-epoxybutane)
bp>200°C and <300°C @ 0.05 mm Hg

	Temp (°C)	Viscosity (cst.)	Slope ASTM #D341
5	20	5688	
	80	72.9	-0.725
	150	6.52	

¹⁹F NMR of Perfluoropoly(1,2-epoxybutane)

	Structure	δ (Multiplicity) ppm vs CFC1 ₃	Rel. Inten. %
10	CF ₂ CF(C ₂ F ₅)O	-77.3, -80.0, 82.2	23.3
	CF ₂ CF(CF ₂ CF ₃)O	-81.0 (s)	35.3
	CF ₃ CF ₂ CF ₂ O	-82.0 (m)	4.2
	CF ₃ CF ₂ CF ₂ O	-84.7 (m)	2.8
15	CF ₂ CF(CF ₂ CF ₃)O	-120 to 127	23.3
	CF ₃ CF ₂ CF ₂ O	-130.3	2.8
	CF ₂ CF(C ₂ F ₅)O	-141.2 (m)	7.8

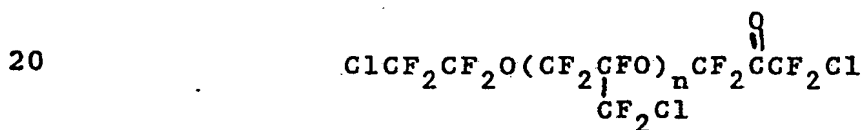
Example 16

A potentially useful nonflammable hydraulic fluid was prepared by placing in a 3 liter, 3 neck flask equipped with a mechanical stirrer, 80g 2-chloroethanol (1.0 mol) and 1 ml boron trifluoride-etherate. To this solution, 462g epichlorohydrin (5.0 mol) was added over a one hour period while the reaction temperature was maintained

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below 50°C throughout the addition. The mixture was stirred for an additional 12 hours at ambient temperature resulting in the formation of a very viscous fluid. The product (403g) was dissolved in 164g chloroform containing 405g 1,1,2-trichlorotrifluoroethane. This solution was metered into an 18°C reactor which contained 5 liters of 1,1,2-trichlorotrifluoroethane. Fluorine gas (20%) was introduced at a rate which was approximately 5% greater than the theoretical amount required to react with all of the hydrogens on the material entering the reactor. Upon completion of the reaction which lasted approximately 20 hours, the reactor was purged with nitrogen to remove the unreacted fluorine gas.

Distillation of the product to remove the fluorination liquid gave 620g of a perfluorinated fluid having substantially the following structure:



M.W. 848; Density (37.8°C): 1.7973 g/ml

Bulk modulus (37.8°C and 3,000 PSIG): 129,700 PSIG

Elemental Analysis: Calculated for an average

structure $\text{C}_{2.11}\text{F}_{4.42}\text{Cl}_{0.8}\text{O}(\text{C}_3\text{F}_5\text{ClO})_3.05\text{C}_{2.11}\text{F}_{4.42}\text{Cl}_{0.8}$

C, 18.92; F, 53.98; Cl, 19.44

Found: C, 18.86; F, 51.15; Cl, 18.26%

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A further treatment of the above product with 30% fluorine at 225°C converted the carbonyl to a di-fluoromethylene group (618g). Following treatment of the product at elevated temperatures with
 5 fluorine the product was distilled. The portion boiling between 50°C and 150°C at 2mm Hg was collected (80% of the sample) and was shown to be a very promising hydraulic fluid candidate. The bulk modulus of the material was measured using an
 10 isothermal secant method. The following results were obtained.

Perfluoropolyepichlorohydrin Type I Bulk Modulus
 M_B @ PSI

	<u>°F @ PSI</u>	<u>1000</u>	<u>2000</u>	<u>3000</u>	<u>4000</u>
15	100°F	129,500	136,700	138,600	145,100
	150°F	180,700	104,200	109,700	115,400

Viscosity of Perfluoropolyepichlorohydrin Type I
 Hydraulic Fluid (monochloro end group)

20	<u>Temp. °F</u>	<u>Viscosity (cst.)</u>
	-65	1198
	100	3.5
	176	1.42

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Example 17

A high molecular weight perfluoropolyepichlorohydrin fluid, having properties similar to those required for a vacuum pump fluid, was prepared by reacting 50g 2-chloroethanol (0.63 mol) with 462g epichlorohydrin (5.0 mol) using a catalytic amount of SnCl_4 . The product (402g), diluted with 275g chloroform and 175g 1,1,2-trichlorotrifluoroethane, was metered into a fluorination reactor over a 20 hour period. The reactor, a 10 liter stirred tank, contained 5.7 liters 1,1,2-trichlorotrifluoroethane. During the course of the reaction the temperature was maintained near 20°C while 20% fluorine was delivered to the reactor at a rate sufficient to react with all of the hydrogens on the product being pumped in. The fluorinated product (573g, 89.8% yield) was separated from the solvent via an atmospheric distillation. The product was treated at 200°C for 12 hours to remove any residual hydrogen and to convert any carbonyl groups present to difluoromethylenes. The portion of the product, approximately 25%, having a boiling point between 200 and 300°C at 0.05 mm Hg was collected. The average molecular weight by ^{19}F NMR end group analysis was approximately 3000. The fluid had a pour point of -22°C.

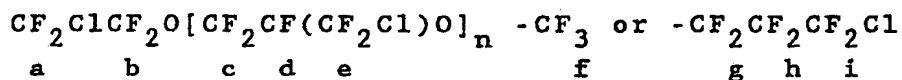
-41-

Viscosity Of Perfluoropolyepichlorohydrin
Vacuum Pump Fluid

	Temp. (°C)	Viscosity (cst.)	Slope ASTM #D341)
5	20	953.7	
	80	26.54	0.763
	150	4.11	

¹⁹F NMR of fraction boiling between 200 and 300°C at
0.05 mm Hg (δ ppm vs CFC1₃);

10 -53.3(f), -67.2(e), -68.6(i), -74.2(a), -77.0 &
-81.0(c), -79.0(g), -87.3(b), -123.7(h), and
-139.3(d).



15 or CF₂CF₂Cl

Example 18

Into a 10 liter, 3 neck flask equipped with a
mechanical stirrer were charged 860g 1,3-dichloro-
2-propanol (617 mol) and 4 ml boron trifluoride-
20 etherate. To this solution was added 1.8 Kg epi-
chlorohydrin (20 mol) over a 2 hour period as the
temperature was maintained below 50°C throughout the
addition with a water bath. The mixture was stirred

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for an additional 12 hours at ambient temperature resulting in a very viscous oil.

A portion of the above epichlorohydrin telomer (1,660g) was dissolved in 164g chloroform containing
5 405g 1,1,2-trichlorotrifluoroethane. The solution was metered into a 10 liter stirred fluorination reactor containing 5.0 liters of 1,1,2-trichlorotrifluoroethane. The reactor was held at 20°C throughout the addition as fluorine gas (20%), diluted with
10 nitrogen, was delivered at a rate slightly above that required to theoretically react with all of the organic feed. The reaction was complete in 36 hours. The crude product was recovered from the solvent by an atmospheric distillation. Treatment
15 of the product with 30% fluorine at 200°C for 12 hours resulted in 4100g of an inert fluid of which approximately 80% boiled between 50 and 150°C at 2mm Hg.

The fluid was shown by ^{19}F NMR end group
20 analysis to have an average molecular weight of 850.

Density (37.8°C): 1.7966 g/ml

Bulk modulus (37.8°C and 3,000 PSIG): 135,400 PSIG

Elemental analysis calculated for an average structure of:

25 $\text{C}_{2.31}\text{F}_{4.46}\text{Cl}_{1.15}\text{O}(\text{C}_3\text{F}_5\text{ClO})_{2.89}\text{C}_{2.31}\text{F}_{4.46}\text{Cl}_{1.15}$
C, 18.77; F, 52.26; Cl, 21.65
Found: C, 18.85; F, 53.13; Cl, 21.51%

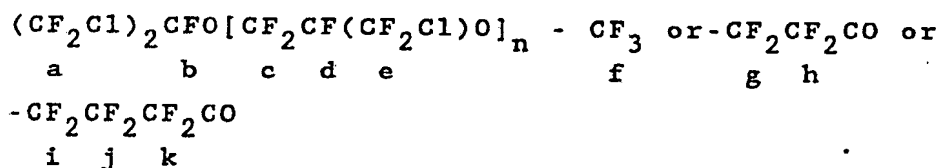
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Viscosity of Perfluoropolyepichlorohydrin Type II
Hydraulic Fluid (Dichloro end group)

	Temp (°F)	Viscosity (cst.)
5	-65	1130
	100	3.35

^{19}F NMR (δ ppm vs CFCl_3)

-53.3(f), -65.6(a), -67.2(e), -68.6(k), -74.3(h),
-77.0(c), -79.0(i), -87.3(g), -123.7(j), -135.2(b)
10 and -139.3(d).



15 Example 19

Trichloropentaerythritol was prepared by
bubbling hydrogen chloride gas into a mixture of
600g acetic acid and 100g of water at 0°C until 176g
had been absorbed (4.9 mol). This mixture was
20 charged into an autoclave along with 200g pentaery-
thritol (1.5 mol). The autoclave was sealed and
heated to 160°C for 8 hours. Upon completion of the
reaction, the autoclave was cooled to room temper-
ature and the reaction mixture was diluted with
25 water. Trichloropentaerythritol acetate was
isolated by extraction with methylene chloride. The

-44-

solvent was removed and the residual oil was re-fluxed overnight with 500 ml of methanol and 50 ml of concentrated hydrochloric acid. Trichloropentaerythritol crystallized from the solution as the methanol and methyl acetate was slowly removed by distillation. The crude product (275g) has a melting point of 60°C.

A 3 liter flask was charged with 267g of trichloropentaerythritol and 1 ml of boron trifluoride-etherate. To this was added 347g of epichlorohydrin (3.75 mol) dropwise over a one hour period while the reaction temperature was maintained below 50°C throughout the addition. The mixture was stirred for an additional 12 hours at ambient temperature resulting in a viscous oil.

The product (612g), diluted with 210g of chloroform and 217g of 1,1,2-trichlorotrifluoroethane, was fluorinated in the usual manner in a 20°C reactor containing 3.7 liters of 1,1,2-trichlorotrifluoroethane. The reaction was complete in approximately 30 hours. The fluid (1,460g) was stabilized by treatment with 30% fluorine for 12 hours at 210°C. The fluid was distilled and the portion boiling between 170°C and 230°C at 50 mm Hg had a viscosity suitable for hydraulic fluid applications. Average molecular weight of the product was 855.

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Viscosity of Perfluoroepichlorohydrin Type III
Hydraulic Fluid (Trichloro end groups)

	Temp (°F)	Viscosity ____(cst.)____
5	-65	1150
	104	3.06
	176	1.46

¹⁹F NMR (δ ppm vs CFC1₃)

10 -48.7(a), -53.3(f), -67.2(e), -68.5(k), -74.3(h),
-77.0(c), -78.8(i), -80.6(b), -87.3(g), -123.8(j)
and -140(d).

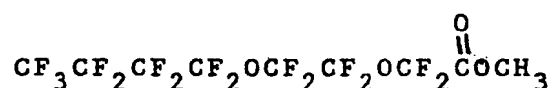
(CF₂Cl)₃C CF₂O[CF₂CF(CF₂Cl)O]_n-CF₃ or -CF₂CF₂Cl or
a b c d e f g h
-CF₂CF₂CF₂Cl
15 i j k

Example 20

Butoxyethoxyethanol (300g, 1.85 mol) was treated with 200g acetyl chloride (2.54 mol) to give an ester which was separated from the product mixture by distillation. A portion of the product (250g) was diluted to a volume of 610 ml with 1,1,2-trichlorotrifluoroethane, then pumped into a -10°C reactor over a 23 hour period. Fluorine gas, diluted with nitrogen, was delivered to the reactor which contained 5 liters of 1,1,2-trichlorotrifluoroethane and 1200 g sodium fluoride powder.

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Upon completion of the reaction, 160g methanol was pumped into the reactor to give the methyl ester which is considerably more hydrolytically stable than the perfluoro ester made in the reaction. The
 5 product (M.W. 460) was obtained in 96% yield.

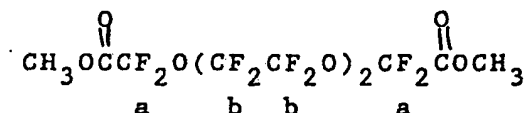
Example 21

A diacetate ester of tetraethylene glycol was
 10 prepared by slowly adding 600g acetyl chloride to 500g tetraethylene glycol in a stirred 2-liter flask. Upon addition of the acetyl chloride, the reaction mixture was heated to 50°C and held at that temperature for 24 hours. Dry nitrogen was bubbled
 15 through the flask for 24 hours to remove the hydrogen chloride, then the product was distilled to give a quantitative yield of the desired product.

The product from the above reaction (247.7g) was fluorinated in a reactor containing 5 liters
 20 1,1,2-trichlorotrifluoroethane and 120g sodium fluoride. The reactor was held at -10°C for approximately 20 hours as the organic was slowly pumped into the reactor. Upon completion of the addition, the unreacted fluorine was swept from the
 25 reactor with nitrogen gas and 200g of methanol was added to give the following product in 93% yield (M.W. 466).

¹⁹F NMR (δ ppm vs CFC1₃): -77.6(a) and -88.4(b).

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The above product was reduced with lithium aluminum
 5 hydride in tetrahydrofuran to give the expected
 methylol derivative in approximately 90% yield.

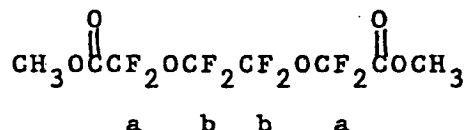
Example 22

A diacetate ester of triethylene glycol was
 prepared by slowly adding 400g acetyl chloride (5.1
 10 mol) to 300g triethylene glycol (2.0 mol) in a
 stirred 1 liter flask. The reaction mixture was
 kept below 50°C throughout the addition. The
 product was recovered by first bubbling dry nitrogen
 through the solution to remove most of the hydrogen
 15 chloride followed by a distillation.

The product from the above reaction (250g) was
 diluted to 600ml with 1,1,2-trichlorotrifluoroethane
 then pumped into a -20°C reactor containing 5 liters
 of 1,1,2-trichlorotrifluoroethane and 1200g sodium
 20 fluoride powder. Fluorine, diluted with nitrogen,
 was bubbled through the liquid fluorination medium
 throughout the addition which required approximately
 18 hours. After purging the reactor for approxi-
 mately 30 minutes, 240g methanol was added and the
 25 reactor was warmed to room temperature. Distil-
 lation of the reactor contents gave 355 grams (95%
 yield) of a product with the following composition.

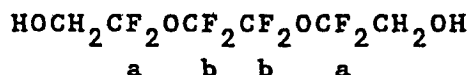
¹⁹F NMR (δ ppm vs CFCl₃): -77.6(a) and -88.3(b)

- 48 -



5 The dimethyl ester was reduced with lithium aluminum anhydride to give the methylol derivative.

^{19}F NMR (δ ppm vs CFCl_3): -80.3(a) and -89.0(b)



Example 23

10 A 200g sample of polypropylene glycol having an
average molecular weight of 425 was diluted to 350
ml with 1,1,2-trichlorotrifluoroethane and slowly
pumped into a 20°C fluorination reactor over a 22
hour period. The reactor contained 4 liters of
15 1,1,2-trichlorotrifluoroethane as the fluorination
liquid. In a separate vessel, 1000g sodium fluoride
pellets were placed. A teflon-diaphragm air pump
was used to circulate the gases present in the
reactor through the sodium fluoride bed and back
20 into the fluorination reactor. Gas velocities in
the recirculating loop of approximately 10 to 20
liters per minute were sufficient to sweep out most
of the hydrogen fluoride formed in the reaction so
that reasonable fluorination yields could be
25 achieved. Following the reaction, 307g of product
(M.W. 1200) was isolated by distillation (53.7%).

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Example 24

In an experiment similar to the one previously described, 202g polypropylene glycol (425 MW) was fluorinated in a reactor containing 3.7 liters of 1,1,2-trichlorotrifluoroethane. Once again, 1000g sodium fluoride pellets were placed in a container which was connected to the fluorination reactor by a circulating gas loop. The reaction temperature was increased to 30°C to see if the hydrogen fluoride could be removed more efficiently. The product (356g) was isolated in 62.2% yield.

Unlike the isotactic perfluoropoly(propylene oxide) which can be made by polymerizing hexafluoropropylene oxide, the perfluorinated fluids described in this example and the previous one were atactic polymers of hexafluoropropylene oxide. The hexafluoropropylene oxide units were attached in a head to tail, head to head and tail to tail fashion. Because of the random structure of these fluids, slightly improved low temperature properties were typically obtained.

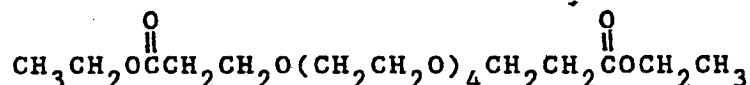
Example 25

To a stirred solution consisting of 194g tetraethylene glycol (1.0 mol) and 4.0g of 50% sodium hydroxide was added 111g acrylonitrile (2.1 mol). The reaction mixture was stirred for three hours at room temperature. 500 ml ethanol was added to the mixture followed by the slow addition of 214 ml of concentrated sulfuric acid (4.0 mol). Upon completion of the addition, the mixture was refluxed

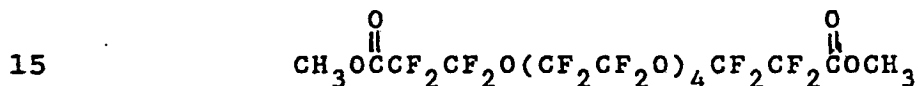
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for seven hours, cooled, then filtered to remove the precipitated solids (NH_4HSO_4). The solids were washed with ethanol and the organic phase was combined with the ethanol rinse solution to give a mixture which upon distillation yielded a product with the following structure (90% yield).



Fluorination of 305 grams of the polyether in a 10°C reactor containing 5 liters of 1,1,2-trichlorotrifluoroethane and 1200g sodium fluoride, followed by treatment with methanol gave 568g of fluid (M.W. 798) having the following structure (92% yield).

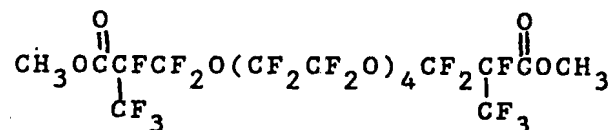


Example 26

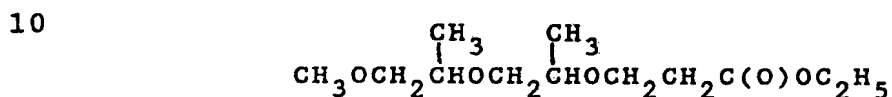
In an experiment similar to the previous one, 194g tetraethylene glycol (1.0 mol) was reacted with 140g methacrylonitrile (2.1 mol) in the presence of 4.0g 50% sodium hydroxide. Treatment of the resulting dinitrile with ethanol and concentrated sulfuric acid yielded the diethyl ester.

Fluorination of the diester (300g) using a fluorination procedure similar to that described in the previous example gave 630g of the product shown below (91% yield).

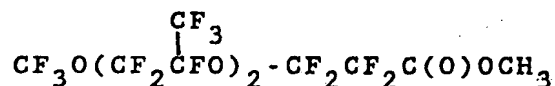
-51-

Example 27

- 5 Using the procedure outlined in Example 25, dipropylene glycol methyl ether was treated with acetonitrile to give a material which upon treatment with ethanol in the presence of sulfuric acid gave of material having the following structure:



- 10 Fluorination of 213g of the material in a -10°C reactor containing 5.3 liters of 1,1,2-trichlorotrifluoroethane and 1050g of sodium fluoride powder
- 15 gave a perfluorinated ester which upon treatment with methanol gave 258g of a functional fluid corresponding to the following structure.



- 20 bp 75°C/15mm Hg

Example 28

- Cyclohexene oxide (250g) was polymerized in 1 liter of n-hexane at -0°C using a catalytic amount of triethylaluminum. The reaction was complete in
- 25 approximately 1 hour. The polymer was first washed

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with concentrated HCl, then water followed by several rinses with methanol.

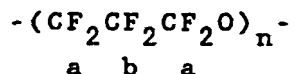
Fluorination of the polymer (205g) using the fluorination techniques outlined in previous
 5 examples gave 413g of a perfluorinated fluid (71% yield).

Example 29

200g polyoxetane was diluted to a volume of 500 ml and was slowly pumped into a 20°C fluorination
 10 reactor containing 5 liters 1,1,2-trichlorotri-
 fluoroethane and 1000g sodium fluoride powder. The polymer was prepared via a ring opening polymeri-
 zation of oxetane or by dehydration of 1,3-pro-
 panediol. The fluorinated product, 335g, was
 15 recovered by first removing the sodium fluoride by
 filtration followed by distillation to remove the
 fluorination solvent.

^{19}F NMR of a sample having a boiling point of
 200-300°C/0.05 mm Hg:

20 (δ ppm vs CFCl_3) -83.3 (s,a), -129.2 (s,b)



Example 30

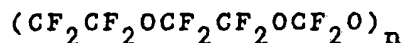
Into a 1 liter stirred flask equipped with a
 25 water separator were placed 500 g diethylene glycol
 (4.7 mol), 90 g diethyl n glycol methyl ether
 (10.75 mol), 225 g paraf rmaldehyde (7.5 mol), 150

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ml toluene and 5 g ion exchange resin (H^+ form).
The mixture was refluxed for several hours to remove
the water formed during the reaction. The solution
was first filtered to remove the ion exchange resin,
5 then distilled to $150^\circ C$ at 0.05 mm/Hg to remove the
toluene and other lights. A nearly quantitative
yield of polymer having an average molecular weight
of 1500 was obtained.

320 g of polymer, mixed with 170 g chloroform
10 and 300 g 1,1,2-trichlorotrifluoroethane was slowly
pumped over a 23 hour period into a 15 liter stirred
fluorination reactor containing 6 liters of
1,1,2-trichlorotrifluoroethane and 1300 g of sodium
fluoride powder. 20% fluorine was bubbled through
15 the liquid fluorination medium at a rate 15% higher
than that required to theoretically replace all of
the hydrogen on the hydrocarbon being pumped into
the reactor. The reactor temperature was maintained
between 0 and $+10^\circ C$ throughout the reaction.
20 Following the reaction, the reactor contents were
filtered and the liquid fluorination medium (1, 1,
2-trichlorotrifluoroethane) was removed from the
filtrate via an atmospheric distillation to $120^\circ C$ to
give 535 g of crude fluid (66%). Fluorination of
25 the fluid at $260^\circ C$ gave a clear, colorless fluid
which was shown by elemental analysis and ^{19}F NMR to
have the following structure:



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Example 31

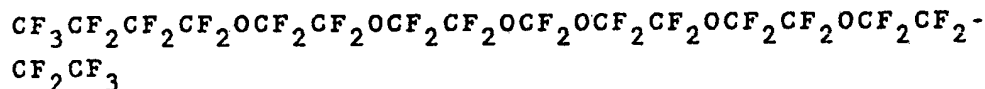
400 g butoxyethoxyethanol (2.5 mol), 48 g paraformaldehyde (1.6 mol), 300 ml benzene and 5 g ion exchange resin (acid form) were placed in a 1 liter stirred flask. A water separator attached to a reflux condenser was used to collect the water produced as the alcohol and aldehyde reacted. After approximately 6 hours, the reaction was complete and the solution was filtered to remove the resin.

Vacuum distillation of the solution to 120°C gave 414 g of a product (99% yield) which was essentially free of benzene and unreacted starting materials.

The hydrocarbon product was fluorinated in a 22 liter stirred tank reactor which contained 6 liters of 1,1,2-trichlorotrifluoroethane and 1300 g sodium fluoride powder. A gas dispersion tube in the bottom of the reactor provided an inlet for the fluorine and nitrogen gasses. 275 grams of the hydrocarbon reactant was diluted with 1,1,2-trichlorotrifluoroethane, in a separate vessel, to give a total volume of 700 ml. This solution was metered into the fluorination reactor over a 20 hour period. The reactor temperature was maintained at 0°C with external cooling throughout the reaction while the fluorine flow was set at a level 10% higher than that required to theoretically replace all of the hydrogens on the material entering the reactor. Upon completion of the reaction, the fluorine was turned off, the reactor was removed from the low temperature bath and purged for 30 min with nitrogen (2 liters/min) to remove the unreacted fluorine.

- 55 -

Filtration of the reaction product followed by distillation to remove the 1,1,2-trichlorotrifluoroethane gave 642 g of a highly fluorinated fluid (80% yield). Treatment of the fluid at 260°C with 30% fluorine for several hours gave a perfluorinated fluid having essentially the following structure:



The elemental analysis was consistent with the
10 formula:

$$C_{17}F_{36}O_6.$$

b. p. 226.5°C

^{19}F NMR (δ ppm vs CFCI_3):

-89.0, -90.7: $\text{CF}_2\text{CF}_2\text{O}$; -51.8: CF_2O ; -81.8, -83.7,
15 -126.7: $\text{CF}_3\text{CF}_2\text{CF}_2\text{CF}_2\text{O}$.

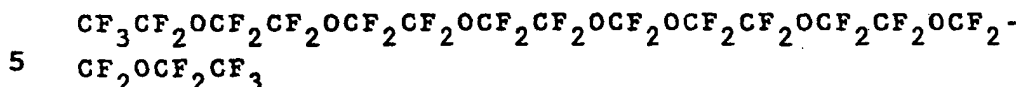
Example 32

A mixture of 400 g triethylene glycol monoethyl ether (2.2 mol), 48 g paraformaldehyde (1.6 mol), 150 ml toluene and 10 g of an acid ion exchange resin was refluxed for 6 hours in a 1 liter flask equipped with a water separator and reflux condenser. Filtration of the product followed by distillation gave a quantitative yield of the desired product.

25 Fluorination of 201 g of the material in a stirred liquid fluorination reactor containing 6 liters of 1,1,2-trichlorotrifluoroethane and 1055 g

- 56 -

sodium fluoride gave 401 g fluid in an 18 hour reaction at 0°C. Distillation of the crude product mixture gave 355 g of the perfluorinated fluid:


$$C_{17}O_8F_{36}$$

b.p. 217°C

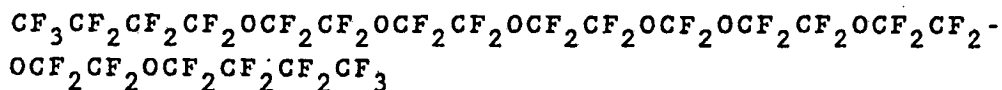
^{19}F NMR (δ ppm vs CFCl_3):

-51.7:CF₂O; -87.3, -90.7:CF₃CF₂; -88.7 CF₂CF₂O.

10 Example 33

Into a 1 liter flask were placed 600 g tri-ethylene glycol butyl ether (2.91 mol), 74 g para-formaldehyde (2.46 mol), 150 ml benzene and 10 g of an acidic ion exchange resin. The mixture was refluxed for 5 hours as water was removed as the water/ benzene azeotrope. Filtration of the product and removal of the benzene by distillation gave a 90% yield of the polyether. 259 grams of the product was diluted with 400 ml 1,1,2-trichlorotrifluoroethane and was slowly metered into a 10°C reactor containing 5.7 liters of 1,1,2-trichlorotrifluoroethane and 1200 g sodium fluoride powder. A Fluorocarbon fluid (660 g, 88.7% yield) was obtained following filtration and removal of the 1,1,2-trichlorotrifluoroethane. Fluorination of the fluid at 220°C with 30% fluorine for 12 hours followed by distillation gave the following fluid in 60% yield:

- 57 -



b.p. 262°C

¹⁹F NMR (δ ppm vs CFC1₃):

5 -88.7, -90.5:CF₂CF₂O; -51.7:CF₂O; -81.6, -83.4,
-126.5:CF₃CF₂CF₂CF₂O.

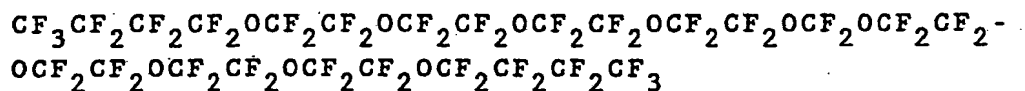
Example 34

Into a stirred 1 liter flask equipped with a water separator were charged 350 g tetraethylene glycol butyl ether (1.40 mol), 35 g paraformaldehyde (1.18 mol), 200 ml benzene and 10 g ion exchange resin. The mixture was refluxed until the water production ceased. Filtration of the product followed by removal of the lights via a vacuum distillation to 140°C gave 343 g of a light yellow fluid.

A 306 g sample of the fluid was diluted with 450 ml of 1,1,2-trichlorotrifluoroethane and slowly pumped into a -6°C reactor over a 23 hour period. The reactor contained 1450 g of sodium fluoride powder to react with the hydrogen fluoride formed during the reaction along with 6 liters of 1,1,2-trichlorotrifluoroethane. Filtration of the product followed by distillation gave 736 g of fluid.

Treatment of the fluid at 250°C with 30% fluorine gave a clear, odorless fluid which upon distillation gave a 52% yield of a material having the following structure:

- 58 -



b.p. 296.7°C

¹⁹F NMR (δ ppm vs CFC1₃):

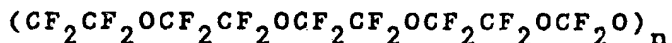
5 -51.8:CF₂O; -88.8, -90.6:CF₂CF₂O; -81.7, -83.6,
-126.7:CF₃CF₂CF₂CF₂O.

Example 35

In a similar experiment, 400 g tetraethylene glycol (2.06 mol), 109 g paraformaldehyde (3.62 mol), 17 g triethylene glycol methyl ether (0.103 mol), 150 ml benzene and 5 g ion exchange resin were allowed to react in a 1 liter flask containing a water separator. After 6 hours, the contents of the flask were filtered and the lights were removed via a vacuum filtration. A 265 g sample of the polymer was mixed with 160 g chloroform and 285 g 1,1,2-trichlorotrifluoroethane. The polymeric solution was metered, over a 22 hour period, into a stirred 10 liter fluorination reactor which contained 1150 g sodium fluoride powder and 4.5 liters of 1,1,2-trichlorotrifluoroethane. The reactor was maintained at 7°C while 20% fluorine (diluted with nitrogen) was metered into the reactor at a rate sufficient to react with all of the organic entering the reactor. Upon completion of the reaction, the solution was filtered and the liquid fluorination medium was removed via a distillation yielding 422 g (62% yield) of a clear, stable fluid. Th product was fractionated into three samples, one which boiled

-59-

below 200°C at 0.05 mm Hg (40%), a second which boiled between 200 and 300°C at 0.05 mm (35%) and a third having a boiling point above 300°C at 0.05 mm Hg (25%). The intermediate fraction had a viscosity of 33.1 cst. at 20°, 6.3 cst. at 80° and 2.13 cst. at 150°C and an average molecular weight of 2560 by ^{19}F NMR. The pour point was -79°C. The analysis was consistent with the formula:



^{19}F NMR (δ ppm vs CFCl_3)
 -51.8: CF_2O ; -56.0: CF_3O ; -88.8, -90.6: $\text{CF}_2\text{CF}_2\text{O}$.
 Anal. Calcd. for $\text{C}_9\text{F}_{18}\text{O}_5$: 20.4, C; 64.5, F.
 Found. 21.0, C; 65.1, F.

Example 36

Dipropylene glycol methyl ether (300 g, 2.04 mol), 60.8 g paraformaldehyde (2.03 mol), 100 ml toluene and 5 g of an acid catalyst were mixed in a stirred 1 liter flask. After refluxing for 12 hours, the solution was filtered and distilled to give 203 g of a fluid which boiled at 140°C at 0.05 mm Hg. The fluid (200 g) was mixed with 300 ml 1,1,2-trichlorotrifluoroethane and 950 g sodium fluoride powder. The reaction was complete in 18 hours after which time the solution was filtered and distilled to give 405 g of a clear liquid having the following structure (71% yield):



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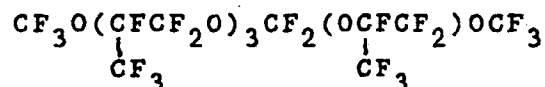
The fluid contains $\text{CF}(\text{CF}_3)\text{CF}_2\text{OCF}(\text{CF}_3)\text{CF}_2\text{O}$,
 $\text{CF}(\text{CF}_3)\text{CF}_2\text{OCF}_2\text{CF}(\text{CF}_3)\text{O}$ and $\text{CF}_2\text{CF}(\text{CF}_3)\text{OCF}(\text{CF}_3)\text{CF}_2\text{O}$
 linkages. The structure was confirmed by ^{19}F NMR
 and elemental analysis:

5 ^{19}F NMR (δ ppm vs CFCl_3): -47.6: CF_3O ; -54.0: CF_2O ;
 -80.0: $\text{CF}(\text{CF}_3)\text{CF}_2\text{O}$; -82 to -87: $\text{CF}(\text{CF}_3)\text{CF}_2\text{O}$; -140 to -150:
 $\text{CF}(\text{CF}_3)\text{CF}_2\text{O}$.

Example 37

10 A mixture of 300 g tripropylene glycol methyl
 ether (6.46 mol), 33.7 g paraformaldehyde (1.12
 mol), 150 ml benzene and 3 g ion exchange resin was
 refluxed for 6 hours in a 1 liter flask equipped
 with a water separator and reflux condenser.
 Filtration of the product followed by vacuum dis-
 15 tillation of the lights gave 166 g of a product with
 a boiling point above 150°C at 0.05 mm Hg.

Fluorination of 145 g of the material, dis-
 solved in 450 ml 1,1,2-trichlorotrifluoroethane, in
 a stirred fluorination reactor containing 6 liters
 20 of 1,1,2-trichlorotrifluoroethane and 700 g of
 sodium fluoride gave 244 g of a fluorocarbon product
 in a 20 hour reaction at -3°C . Distillation of the
 product gave 180 g of the perfluorinated fluid:



25 where the hexafluoropropylene oxide units are
 attached randomly in a head to head, head to tail
 and tail to tail fashion.

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^{19}F NMR (6 ppm vs CFCl_3): -47.3, -56.0: CF_3O ; -
54.0: CF_2O ; -80.0 $\text{CF}(\text{CF}_3)\text{CF}_2\text{O}$; -83.0, -
85.3: $\text{CF}(\text{CF}_3)\text{CF}_2\text{O}$; -145.3, -146.0: $\text{CF}(\text{CF}_3)\text{CF}_2\text{O}$.

b.p. 260.0°C.

5 Example 38

A mixture of 400 g dipropylene glycol (3.0 mol), 358 g paraformaldehyde (12 mol), 150 ml toluene and 10 g ion exchange resin was refluxed for 5 hours in a stirred 1 liter flask equipped with a water separator. The ion exchange resin was removed prior to distillation of the mixture to 150°C under a full vacuum to remove any low molecular weight polymer. Approximately 200 g of polymer remained in the flask which was shown by gel permeation chromatography to have an average molecular weight of approximately 3000.

The polymer, 280 g, was mixed with 340 ml 1,1,2-trichlorotrifluoroethane and was slowly pumped into a 15 liter stirred reactor over a 24 hour period. The reactor, which contained 5.5 liters of 1,1,2-trichlorotrifluoroethane and 1220 g sodium fluoride powder, was maintained at 10°C throughout the reaction while 20% fluorine was bubbled through the liquid fluorination medium at a rate just exceeding that required to react with all of the starting material being pumped into the reactor. The reactor contents were filtered and distilled to give 587 g of fluid which was further treated with 50% fluorine at 270°C to give a fluid which was essentially free of hydrogen. The purified product

-62-

was fractionated into three samples. The first fraction boiled below 200°C at 0.05 mm Hg, the second distilled over between 200 and 300°C at 0.05 mm and the distillation bottoms had a boiling point above 300°C at 0.05 mm Hg. The second fraction comprised approximately 20% of the total fluid with the majority of the sample having a boiling point below 200°C at 0.05 mm. The second fraction had an average molecular weight of 2500 by ¹⁹F NMR.

The viscosity of the second fraction at 20°C was 72.2 cst. (ASTM slope of 0.644). The pour point was -62°C.

¹⁹F NMR (δ ppm vs CFC1₃): -47.3, -49.3, -51.4: CF₂O; -54.0, -55.8: CF₃O; -79.7: OCF(CF₃)CF₂O; -81.8, -82.8, -84.7: OCF(CF₃)CF₂O; -87.3: CF₃CF₂O; -130.0: CF₃CF₂O; -140.3, -144.8, -146.0: OCF₂CF(CF₃)O.

Anal. Calcd. for CF₃O[CF₂CF(CF₃)OCF₂CF(CF₃)OCF₂O]_n-CF₂CF₃: C, 21.02; F, 67.02.
Found. C, 21.08; F, 67.08.

20 Example 39

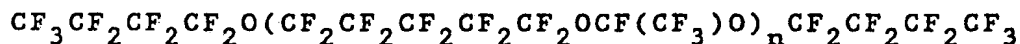
A mixture of 600g 1,5-pentanediol and 30g potassium hydroxide was heated to 160°C in a 1 liter flask. Acetylene gas was bubbled through the solution as it was rapidly stirred. The reaction was stopped after 40 hours and the product was washed with water and distilled to give an 85% yield of pentan diol divinyl ether (b.p. 192°C).

A 1 liter flask cooled to -12°C was charged with 104g pentanediol and a trace of methane

-63-

sulfonic acid. To this solution was added 156g pentanediol divinyl ether. The solution was stirred rapidly for 2 hours. Then slowly warmed to room temperature over a 6 hour period to give a viscous polymer having viscosity of 650 cst. at 100°F.

The product from the above reaction was fluorinated in a liquid phase reactor containing 1,1,2-trichlorotrifluoroethane and a sufficient amount of fluorine to complex with all of the hydrogen fluoride formed during the reaction. A perfluoropolyether (average molecular weight of 1800) having the following structure was obtained:



Example 40

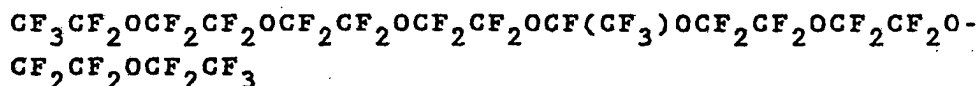
A mixture of 400 g triethylene glycol ethyl ether (2.24 mol), 258 g acetaldehyde diethylacetal (1.39 mol), 300 ml benzene and 10 g acidic ion exchange resin was refluxed in a 1 liter stirred flask equipped with a continuous extractor to remove the by-product ethanol from the refluxing benzene. The solution was refluxed for 6 hours, then filtered and placed in a rotary evaporator to remove the benzene solvent.

The product was fluorinated in a 22 liter stirred tank which contained 5.7 liters of 1,1,2-trichlorotrifluoroethane and 1100 g sodium fluoride powder. The hydrocarbon (219 g) was diluted to a volume of 700 ml with 1,1,2-trichlorotrifluoroethane. The solution was slowly pumped into the

-64-

fluorination reactor, which was held at -5°C, over a period of 28 hours. The fluorine flow was set at a level approximately 10% higher than that required to react with all of the organic entering the reactor.

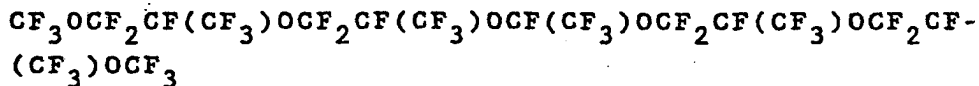
- 5 Filtration of the crude reactor product followed by distillation yielded 224 g of a clear fluid which analyzed to be:



- 10 ^{19}F NMR (δ ppm vs CFCl_3): -86.5: $\text{OCF}(\text{CF}_3)$; -87.4: $\text{CF}_3\text{CF}_2\text{O}$; -88.0: $\text{CF}_3\text{CF}_2\text{O}$; -88.7: $\text{OCF}_2\text{CF}_2\text{O}$; -96.3: $\text{OCF}(\text{CF}_3)\text{O}$.

Example 41

- 15 In an experiment very similar to the previous one, 400 g dipropylene glycol monomethylether (2.70 mol) was reacted with 159.5 g acetaldehyde diethylacetal (1.35 mol) in benzene with an acid catalyst. Fluorination of 250 g of the material afforded 480g of a perfluorinated fluid having the
- 20 following structure:

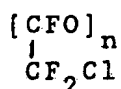


Example 42

- 25 Chloroacetaldehyde (50 to 55 wt % in water) was distilled to give a fraction boiling between 87 and 92°C. A 3 liter stirred flask containing 1281 g of the chloroacetaldehyde distillate was placed in a

-65-

room temperature water bath. While maintaining a temperature below 55°C, 500 ml of concentrated sulfuric acid was slowly added over a one hour period. The mixture was stirred for an additional 3 days at 53°C, then allowed to separate into two phases. The lower phase, containing sulfuric acid, was removed with a separatory funnel while the upper phase was placed into a 3 liter flask equipped with a mechanical stirrer. Concentrated sulfuric acid (200 ml) was carefully added to the solution while the temperature was held below 60°C with a water bath throughout the addition. The flask was held at 50°C for an additional 20 hours resulting in a viscous oil being formed. The polymeric product was dissolved in 1 liter methylene chloride and the solution was washed with water several times followed by a rinse with dilute sodium bicarbonate solution. The organic phase was isolated, dried over magnesium sulfate and concentrated to give a dark, viscous product (719 g polychloroacetaldehyde). The product was dissolved in 450 g chloroform and 305 g 1,1,2-trichlorotrifluoroethane to give a solution which was metered over a 22 hour period into a 20°C fluorination reactor containing 5.5 liters of 1,1,2-trichlorotrifluoroethane. Following the reaction, the solvent was removed leaving behind a fluid with the following structure having an average molecular weight of 850:

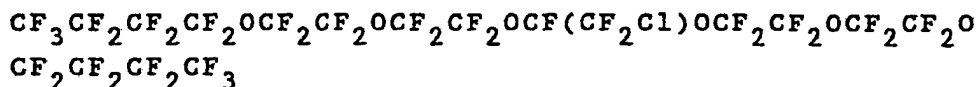


-66-

<u>Temp. °F</u>	<u>Viscosity (cst.)</u>
-65	1240
100	2.53
176	1.14

5 Example 43

Butoxyethoxyethanol (400 g, 2.47 mol) was reacted with 130 g polymeric chloroacetaldehyde in 150 ml benzene to give a fluid which distilled at 190°C at approximately 1 torr. The product (266 g) was mixed with 500 ml 1,1,2-trichlorotrifluoroethane and pumped into a 15 liter fluorination reactor containing 5.7 liters 1,1,2-trichlorotrifluoroethane and 1150 g sodium fluoride powder. Fluorine, diluted with approximately four volumes of nitrogen, was metered into the 0°C reactor at a rate approximately 10% greater than that required to react stoichiometrically with the polyether. The organic feed rate was set to allow complete addition in approximately 23 hours. Filtration of the product and removal of the 1,1,2-trichlorotrifluoroethane via a distillation gave a fluorocarbon product which was further purified by a 12 hour fluorination at 200°C with 40% fluorine. Approximately 520 g of fluid was recovered with approximately 50% being the target material.

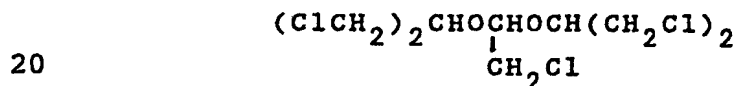


-67-

b.p. 245.5°C

 ^{19}F NMR (δ ppm vs CFCl_3)-73.3: $\text{OCF}(\text{CF}_2\text{Cl})\text{O}$; -81.7: $\text{CF}_3\text{CF}_2\text{CF}_2\text{CF}_2\text{O}$;-83.3: $\text{CF}_3\text{CF}_2\text{CF}_2\text{CF}_2\text{O}$; -88.0 and -88.7: $\text{OCF}_2\text{CF}_2\text{O}$;5 -96.7: $\text{OCF}(\text{CF}_2\text{Cl})\text{O}$; -126.5: $\text{CF}_3\text{CF}_2\text{CF}_2\text{CF}_2\text{O}$.Example 44

Chloroacetaldehyde dimethyl acetal (124 g, 1 mol), 1,3-dichloro-2-propanol (258g, 2 mol) and 5g ion exchange resin were mixed in a 1 liter stirred flask. The mixture was heated to allow the methanol formed in the reaction to slowly distill from the flask. Approximately 70 ml of methanol was recovered over a 6 hour period. The remaining solution was vacuum-distilled and the fraction (120 g, 38% yield) boiling between 100°C and 145°C at 2 mm Hg was collected. The fluid was shown by ^{19}F NMR and elemental analysis to have the following structure:



The above acetal (210 g) diluted with a small amount of chloroform and 1,1,2-trichlorotrifluoroethane was metered over a 14 hour period into a 22°C fluorination reactor containing 5.7 liters of 1,1,2-trichlorotrifluoroethane. The crude product was further treated with 30% fluorine at 200°C for several hours to give 197g (57% yield) of clear fluid:

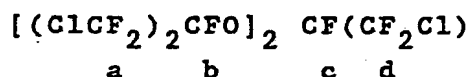
-68-



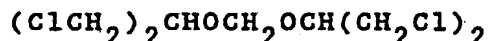
b.p.: 202°C

¹⁹F NMR (δ ppm vs CFC1₃): -64.5 and -65.0(a),

5 -71.0(d), -86.7(c) and -133.7(b)

Example 45

Into a 1 liter stirred flask containing 300 ml
 10 benzene were placed 516 g 1,3-dichloro-2-propanol (4
 mol), 120 g paraformaldehyde (4 mol) and 10g ion
 exchange resin. The mixture was refluxed as the
 water formed during the reaction was continuously
 removed. After refluxing for 6 hours, the reaction
 15 mixture was filtered and vacuum-distilled to give
 354 g of a product with the following structure:

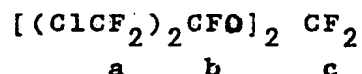


b.p.: 141°C/0.05 mm Hg.

The above acetal (354 g) was mixed with 70 g
 20 chloroform and 360 g 1,1,2-trichlorotrifluoroethane
 and fluorinated over a 24 hour period at 20°C using
 the procedure described in the previous example.
 The reaction product was concentrated and the crude
 product was further treated with fluorine at 200°C
 25 to give 430 g of a clear fluid (69% yield) having a
 boiling point of 178°C.

-69-

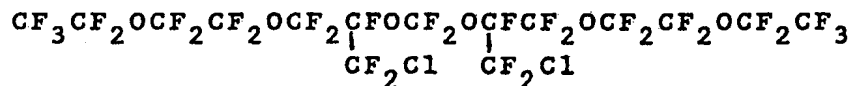
^{19}F NMR (δ ppm vs CFC_3): -45.5(c), -65.3(a) and -137.1(b)



5 Example 46

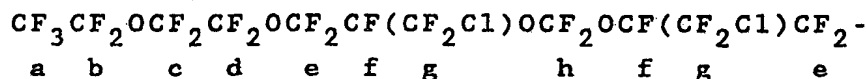
A mixture of 600 ml ethoxyethanol, 200 g epichlorohydrin and 10 g ion exchange resin was heated to 130°C for 20 hours. The reaction mixture was then cooled, filtered and distilled to give 250 g of product which was then reacted with 116 g paraformaldehyde to give 266 g of a product boiling above 150°C at 0.01 mm Hg.

Fluorination of 261 g of the product in a reactor containing 5 liters of 1,1,2-trichlorotri-fluoroethane and 1000 g sodium fluoride gave 446 g of perfluorinated fluid of which approximately 70% had the following structure:



20 b.p. 224°C

^{19}F NMR (δ ppm vs CFC_3): -46.4(h), -67.6(g), -80.9(e), -87.6(a), -89.0(b,c,d), and -141.8(f)



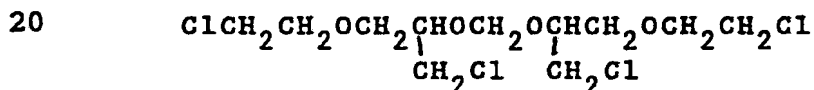
25 $\text{OCF}_2\text{CF}_2\text{OCF}_2\text{CF}_3$
d c b a

-70-

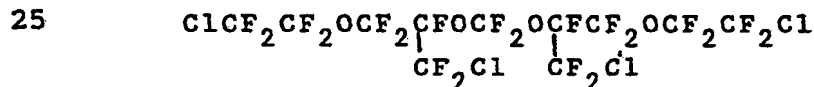
Example 47

A mixture consisting of 100g 2-chloroethanol (12.4 mol), 573g epichlorohydrin (6.2 mol) and 20g of an acidic ion exchange resin was refluxed for 24 hours. The mixture was then filtered to remove the ion exchange resin and the excess alcohol and unreacted epichlorohydrin were removed by distillation. The residue was distilled under vacuum and the product 1-chloro-3-(2-chloroethoxy)-2-propanol (804g, 75% yield) distilled between 89 and 91°C at 0.05mm Hg.

Into a 1-liter stirred flask were placed 346g 1-chloro-3-(2-chloroethoxy)-2-propanol (2 mol), 90g paraformaldehyde (3 mol), 10g ion exchange resin and 300ml benzene. The mixture was refluxed for four hours as the water formed during the reaction was removed. The reaction mixture was filtered and distilled to give 267g of a product (75% yield) with the following structure:



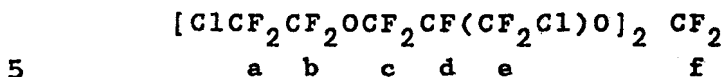
Fluorination of the product (660g) in a typical reaction at 20°C gave 1086g of a product (82% yield) having the following structure:



-71-

b.p.: 223°C

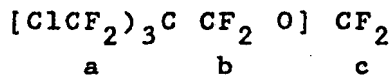
¹⁹F NMR: (δ ppm vs CFC1₃): -46.3(f), -67.3(e),
-74.3(a), -81.0(c), -87.3(b) and -141.9(d)

Example 48

Into a 1 liter flask were charged 300 g trichloropentaerythritol, (1.58 mol), 150 ml of benzene, 10 g ion exchange resin and 60 g paraformaldehyde (2 mol). The mixture was refluxed as water was being removed continuously.

A portion of the above product, 192 g, was diluted with 1,1,2-trichlorotrifluoroethane to give 210 ml of solution which was pumped into a 22°C reactor containing 4.3 liters of 1,1,2-trichlorotrifluoroethane. The reaction was complete in approximately 8 hours. The unreacted fluorine was flushed from the reactor with nitrogen gas and the product (307 g, 87.8% yield) was recovered by distillation:

¹⁹F NMR (δ ppm vs CFC1₃): -48.9(a), -51.1(c),
-66.4(b)

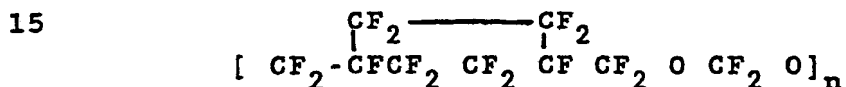


-72-

Example 49

A mixture of 392 g 1,4 cylcohexanedimethanol (2.72 mol), 140 g paraformaldehyde (4.7 mol), 200 ml benzene and 10 g of a H⁺ ion exchange resin was
 5 refluxed for several hours in a flask containing a water separator. A nearly quantitative yield of a sticky solid was obtained after removal of the solvent by distillation.

Fluorination of 263 g of the polymer, diluted
 10 with 220 g chloroform and 340 g 1,1,2-trichlorotrifluoroethane in a reactor (10°C) containing 4.8 liters 1,1,2-trichlorotrifluoroethane and 1300 g sodium fluoride power, gave 440g of a perfluoro-polyether having the following structure:

Example 50

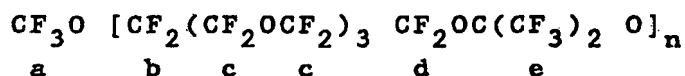
Into a 1 liter flask were placed 350 g tetraethylene glycol (1.8 mol), 300 ml benzene, and
 20 10 g ion exchange resin. The mixture was refluxed for 1 hour to remove any moisture present. To the mixture was added 200 ml dimethoxypropane. The distillate was continuously removed over a 2-hour period in 50 ml increments, which were extracted
 25 with water to remove the ethanol formed in the reaction. After drying, the distillate was returned to the flask. An additional 200 ml dimethoxypropane was added and the distillate was collected, extracted, dried, and returned to the flask for an

-73-

additional 3 hours. Removal of the resin and solvent yielded 410 g of a polymeric fluid having a viscosity of 560 cst. at 30°C.

5 Fluorination of 336 grams of the polyether in a 10°C reactor containing 5 liters of 1,1,2-trichlorotrifluoroethane and 1420 g sodium fluoride powder gave 642 g of a perfluoropolyether having an average molecular weight of 1700 (69.8% yield).

¹⁹F NMR: (δ ppm vs CFC1₃): -55.8(a), -76.3(e),
10 -87.3(d), -88.6(c) and -90.5(b)



Example 51

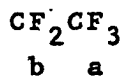
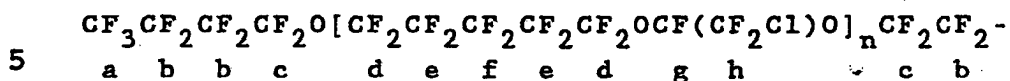
A mixture of 300 g pentanediol (2.88 mol), 450
15 g chloroacetaldehyde/water mixture having a boiling point between 87 and 92°C and 150 ml benzene was refluxed in a flask containing a water separator. Approximately 5 grams of an acidic ion exchange resin was added to catalyze the reaction. After
20 refluxing for approximately five hours the solution was filtered and the benzene was removed by distillation to leave a residue (approximately 400 g) having a viscosity of 9,700 cst. at 100°F.

Fluorination of 318 g of the polymer, diluted
25 with 235 g chloroform and 375 g 1,1,2-trichlorotrifluoroethane, in a 12°C reactor containing 5 liters of 1,1,2-trichlorotrifluoroethane and 1200 g sodium fluoride powder gave 623 g (84% yield) of the fluorinated polyether (average molecular weight of
30 2100) in a 22-hour reaction.

-74-

^{19}F NMR (δ ppm vs CFCl_3):

-73.4(h), -74.3(c), -81.6(a), -82.3(d), -87.1(g),
-122.1(f), -125.3(e) and -126.3(b)



Example 52

10 A ten-liter stirred tank reactor was filled
with 5.5 liters 1,1,2-trichlorotrifluoroethane.
220.3 grams of phenanthrene was placed in a one-
liter brass tube fitted with a plug of copper
turnings in each end of the tube and then filled
with 1,1,2-trichlorotrifluoroethane. This brass
15 tube was then placed in the liquid return line of
the condenser so that the 1,1,2-trichlorotrifluoro-
ethane condensed in the condenser would flow through
the brass tube and dissolve some phenanthrene before
entering the reactor. The fluorine flow was set at
20 470cc/min and the nitrogen flow was set at two
liters per minute. The reactor temperature and the
brass tube containing the phenanthrene were both
held at 19°C during the reaction. After 20 hours,
the fluorine was stopped and the reactor was dumped.
25 In the brass tube, 21.8 grams of phenanthrene
remained so a total of 198.5 grams had reacted.

-75-

From the reactor, after removal of the 1,1,2-trichlorotrifluoroethane, a pale yellow liquid was recovered. This material was then reacted with 40cc/min fluorine and 100cc/min nitrogen in an
5 unstirred reactor where the fluorine was bubbled through the liquid at 200°C for 12 hours to give a clear, colorless liquid. This liquid was then distilled to give 517g (74.2%) of perfluorotetradecahydrophenanthrene (b.p. 215°C) along with 128
10 grams of a clear, colorless solid that melted at approximately 60°C and was much less volatile than the perfluorotetradecahydrophenanthrene.

Example 53

5.3 liters 1,1,2-trichlorotrifluoroethane were
15 placed in a ten-liter stirred tank reactor. 256 grams of kerosene was diluted to 650 ml with 1,1,2-trichlorotrifluoroethane. The fluorine flow was set at 650cc/min with the nitrogen flow at 2 liters per minute. After three minutes the kerosene solution
20 was added at 25ml/hr to the reactor and the reaction was continued under these conditions while holding the reactor temperature at about 10°C. After 26 hours, all of the kerosene had been added and the fluorine flow was stopped fifteen minutes later.
25 The product was distilled to remove the 1,1,2-trichlorotrifluoroethane and any other material with a boiling point below about 100°C. 575 grams of a clear, colorless liquid product was obtained after treatment with 30cc/min fluorine and 60cc/min N₂ at
30 150°C for 15 hours.

-76-

Example 54

A ten-liter stirred tank reactor was loaded with 3.3 liters 1,1,2-trichlorotrifluoroethane. 120 grams of heavy mineral oil was diluted to 480 ml
5 with 1,1,2-trichlorotrifluoroethane. The fluorine flow was set at 350cc/min with a nitrogen flow of 1.5 liters per minute. The mineral oil was added to the reactor at a rate of 20ml/hr. After 24 hours, the reaction was complete and the reactor was
10 dumped. After removal of the 1,1,2-trichlorotrifluoroethane, 385 grams of product was obtained. This product was then treated with 30cc/min fluorine and 60cc/min nitrogen at 200°C for 16 hours to give 306 grams of a soft paste that became a completely
15 clear, colorless liquid at approximately 80°C.

Example 55

A ten-liter stirred tank reactor was loaded with five liters of 1,1,2-trichlorotrifluoroethane. 202 grams of Amoco Indopol™ H-100 polybutene (MW
20 920) was diluted to 610 ml with 1,1,2-trichlorotrifluoroethane. The fluorine flow was set at 460cc/min with a nitrogen flow of 1.5 liters per minute. The polybutene was then added at a rate of 25 ml/hr while the reactor was held at -3°C. Once
25 all the polybutene had been added (24 hours), the fluorine was reduced to 300cc/min and the nitrogen reduced to 1.2 liters per minute and these conditions were maintained for 15 minutes after which the fluorine flow was stopped and the reactor was

-77-

dumped. After removal of the 1,1,2-trichlorotrifluoroethane, the product was placed in a 600 ml beaker on a hot plate in a fume hood for eight hours at approximately 120°C to remove any light fraction in the oil. 496 grams of a viscous, colorless, slippery oil was obtained that has a pour point of about -15°C and an average molecular weight of 1500.

Example 56

A ten-liter stirred tank reactor was loaded with 5.0 liters 1,1,2-trichlorotrifluoroethane. 216 grams of Uniroyal Chemical's Trilene™ CP80 ethylene propylene copolymer (molecular weight approximately 8000) was diluted in 1,1,2-trichlorotrifluoroethane to give 800 ml. The fluorine flow was started at 420cc/min and the nitrogen flow was at 1.6 liters/minute. After a few minutes, the CP80 solution was added at 25ml/hr while the reactor was held at 10°C. After 31 hours, all of the CP80 solution had been added but the fluorine concentration in the gas outlet line rose only slowly. After one hour, the fluorine flow was reduced to 200cc/min with a nitrogen flow of 800cc/min and the conditions were held for five hours after which time the fluorine flow was stopped. When the reactor was dumped, a gelatinous product was obtained that was insoluble in the 1,1,2-trichlorotrifluoroethane. When all of the 1,1,2-trichlorotrifluoroethane was removed from the gelatinous product, 680 grams of somewhat brittle white solid was left. A small portion of this solid was ground into a powder and

-78-

20 grams was placed in a one-foot-long copper boat. This copper boat was placed in a 1"x18" nickel tube and exposed to pure fluorine at 85°C for 20 hours (5cc/min F₂ flow). When this was done there was
5 20.6 grams of a very viscous, clear, colorless elastomer in the boat which was insoluble in 1,1,2-trichlorotrifluoroethane and all other solvents tried.

Example 57

10 A ten-liter stirred tank reactor was loaded with 5.0 liters 1,1,2-trichlorotrifluoroethane. 275 grams of poly(alpha-methylstyrene) (having an average molecular weight of 685) was dissolved in
15 400g chloroform and 400g 1,1,2-trichlorotrifluoroethane to give about 800 ml. The fluorine flow was set at 350cc/min and the nitrogen flow was set at 1400cc/min. The poly(alpha-methylstyrene) solution was added at a rate of 20ml/hr while the reactor temperature was held at 12°C. After 39 hours, all
20 of the poly-(alpha-methylstyrene) solution had been added and the fluorine flow was left on for one more hour. When the reactor was dumped, a pale yellow solution was recovered which contained approximately one gram of insoluble white powder. The solution
25 was filtered and the 1,1,2-trichlorotrifluoroethane was removed by distillation to give 785 grams of a pale yellow, somewhat brittle solid that melted at about 50°C. The melting point of the solid could be raised by distilling some of the low molecular
30 weight product out of the solid. Approximately one third of the product boiled below 175°C at 1 torr.

-79-

Example 58

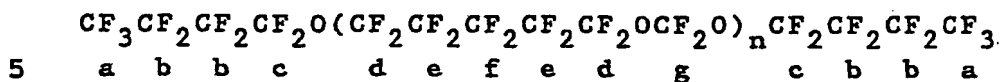
3.7 liters 1,1,2-trichlorotrifluoroethane were placed in a ten-liter stirred tank reactor. 69g tri-n-hexylamine and 54g trifluoroacetic acid were
5 diluted in 1,1,2-trichlorotrifluoroethane to give 300 ml. The fluorine flow was set at 400cc/min and the nitrogen flow was set at 1600cc/min. The trihexylamine was added at 35ml/hr while the reactor was maintained at 22°C. When all of the amine had
10 been added (8 hours), the fluorine flow was reduced to 100cc/min with the nitrogen at 800cc/min. These conditions were maintained for four hours after which time the fluorine was turned off and the reactor was dumped. The product consisted of a
15 colorless liquid with a thick, brown tar floating on top and coating the walls of the reactor. The soluble phase contained 71 grams of perfluorotrihexylamine (37%).

Example 59

20 Into a 1 liter stirred flask were placed 350g 1,5 pentanediol (3.4 mol), 23g n-butanol (0.3 mol), 175g paraformaldehyde (5.8 mol) and 200 ml benzene. Upon refluxing the mixture for approximately 3 hours with an acid catalyst present, 390g of a polymeric
25 fluid was obtained which had a viscosity of 450 cst. at 100°F. Fluorination of 310g of the fluid in a typical fluorination reaction at 14°C gave 708g of fluid (80% yield) of which approximately 30% boiled between 200 and 300°C at 0.05 mm Hg. Th average
30 molecular weight was 2800.

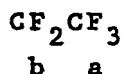
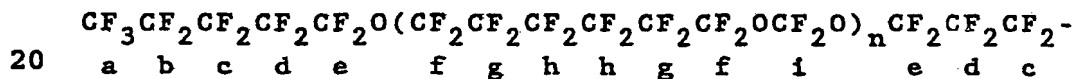
-80-

^{19}F NMR (δ ppm vs CFCl_3)-51.3(g), -55.7(c),
-81.7(a), -85.0(d), -122.3(f), -125.5(e) and
-126.7(b)

Example 60

Using techniques similar to those described in the previous examples, 350g 1,6-hexanediol (3.0 mol) 49.3g n-pentanol (0.56 mol), 134g paraformaldehyde
10 (4.46 mol) were reacted in benzene to give 425g of a polymeric material having a viscosity of 600 cst. at 100°F. Fluorination of 628g of the fluid in a typical reaction at 10°C gave 628g of fluid (71% yield), of which approximately 30% boiled between
15 200 and 300°C at 0.05 mm Hg.

^{19}F NMR (δ ppm vs CFCl_3):-51.3(i), -56.0(b),
-81.7(a), -85.0(f), -85.3(e), -122.7(h), -123.0(c),
-125.5(g) and -126.3(d)

Example 61

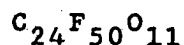
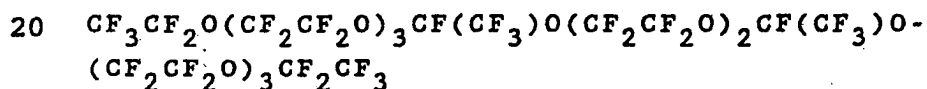
A mixture of 600g diethylene glycol and 30g
25 potassium hydroxide was heated to 160°C in a 1 liter flask. Acetylene gas was bubbled through the

-81-

solution as it was rapidly stirred. The reaction was stopped after 48 hours and the product was extracted with water several times to remove any unreacted diethylene glycol. The product, a divinyl ether of diethylene glycol, was recovered by distillation (b.p. 196°C) in about an 80% yield.

A 1 liter flask cooled to -10°C was charged with 250g triethylene glycol ethyl ether and a catalytic amount of methane sulfonic acid. To this solution was added slowly 100g diethylene divinyl ether. Following the addition, the flask was slowly warmed to room temperature over a 3 hour period. The product was distilled to 150°C at 0.05 mm Hg to remove any unreacted starting materials.

The product from the above reaction can be fluorinated at 20°C using the procedures outlined in the previous liquid phase fluorination examples to give a perfluorinated fluid of the following structure:



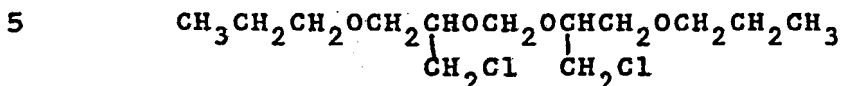
b.p. 300°C

Example 62

A mixture of 300g 1-propanol (5.0 mol), 231 g epichlorohydrin and 10 g ion exchange resin was refluxed for 22 hours. The reaction mixture was then cooled, filtered and distilled to give 281 g of

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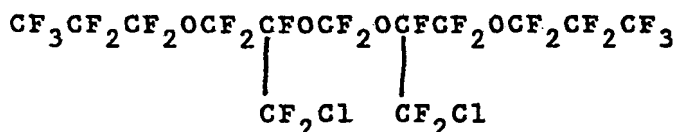
1-chloro-3-propoxy-2-propanol (74% yield). Reaction of this product with paraformaldehyde (2.8 mol) gave 202 g of product (69% yield) having the following structure:



b.p.: 132°C at 2 mm Hg.

Fluorination of the above acetal in a 23 hour reaction at 20°C gave 404 g or product (81% yield)

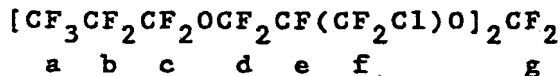
10 having the following structure:



b.p.: 207°C

¹⁹F NMR (δ ppm vs CFC1₃): -46.3(g), -67.3(f),

15 -80.4(d), -81.9(a), -84.5(c), -130.0(b) and
-141.6(e)



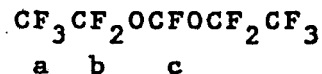
Example 63

20 Eighty grams of diethoxymethane were fluorinated in a 4-liter stirred tank reactor containing 1.5 liters $(\text{CF}_2\text{Cl})_2\text{CFOCF}_2\text{OCF}(\text{CF}_2\text{Cl})_2$ as a fluorination solvent and 400 g sodium fluoride powder. The diethoxymethane, diluted with 200 ml of

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(CF₂Cl)₂CFOCF₂OCF(CF₂Cl)₂ was pumped into the reactor over an 18 hour period. Fluorination of the fluid at 10°C with 30% fluorine gave a 90% yield of a product having a boiling point of 92.5°C. The product was obtained in greater than 99% purity following an atmospheric distillation.

¹⁹F NMR (84.87 MHz, CFC1₃) -52.4 (pentet, c), -87.3 (singlet, a), -90.1 (triplet, b).

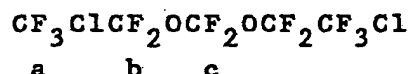


10 Example 64

A mixture consisting of 500g 2-chloroethanol (6.25 moles), 120g paraformaldehyde (4 moles), 5g of an acidic ion exchange resin and 100ml benzene was refluxed for several hours. The water formed during the reaction was continuously removed. The mixture was filtered to remove the ion exchange resin and the unreacted 2-chloroethanol and benzene were removed by distillation. The residue was distilled to give bis(2-chloroethoxy)methane in a nearly quantitative yield. One hundred twenty grams of the product was fluorinated in a 4 liter stirred reactor containing 1.5 liters (CF₂Cl)₂CFOCF₂OCF(CF₂Cl)₂ in a 30 hour reaction at 20°C to give a 92% yield of perfluoro[bis(2-chloroethoxy)methane]. The product (b.p. 92.5°C) was obtained in greater than 99% yield by distillation.

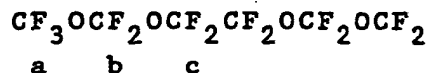
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^{19}F NMR (84.87 MHz, CFCl_3) -52.1 (pentet, c), -74.0 (singlet, a); -88.8 (triplet, b).

Example 65

- 5 The reaction of 500g dimethoxymethane (6.6 moles) with 100g 1,3-dioxolane (1.4 moles), in the presence of an acidic catalyst, gave a mixture of unreacted dimethoxymethane, low molecular weight oligomers of 1,3-dioxolane and a product having the
- 10 formula: $\text{CH}_3\text{OCH}_2\text{OCH}_2\text{CH}_2\text{OCH}_2\text{OCH}_3$ which was isolated in 50% yield. Fluorination of 80g of the product in a 4 liter reactor containing 1.5 liters
- 15 $(\text{CF}_2\text{Cl})_2\text{CFOCF}_2\text{OCF}(\text{CF}_2\text{Cl})_2$ and 400g sodium fluoride in an 18 hour reaction at 10°C , gave a 60% yield of perfluoro-2,4,7,9-tetraoxadecane (b.p. 79.0°C).

^{19}F NMR (84.87 MHz, CFCl_3) -54.1 (pentet, b) -57.7 (triplet, a), -90.9 (triplet, c).

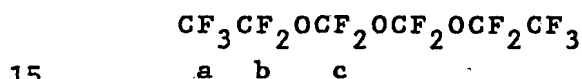
Example 66

- 20 3,5,7-trioxanonane was prepared in low yield by reaction of 500g ethanol (10.9 moles) with 500g paraformaldehyde (16.7 moles) in 200 ml of benzene containing 5g of an acidic ion exchange resin. The reaction was done in a 2 liter flask equipped with a

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water separator and reflux condenser. The major product formed, diethoxymethane, was removed from the product mixture along with the benzene by distillation. The remaining residue contained low molecular weight oligomers of formaldehyde having the general formula: $\text{CH}_3\text{CH}_2(\text{OCH}_2)_n\text{OCH}_2\text{CH}_3$. The primary component, $\text{CH}_3\text{CH}_2\text{OCH}_2\text{OCH}_2\text{OCH}_2\text{CH}_3$ was isolated in about a 10% yield. Fluorination of the product in $(\text{CF}_2\text{Cl})_2\text{CFOCF}_2\text{OCF}(\text{CF}_2\text{Cl})_2$ containing sodium fluoride gave a 45% yield of perfluoro-3,5,7-trioxanonane.

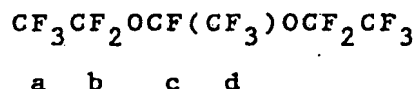
^{19}F NMR (84.87 MHz, CFCl_3) -53.7 (multiplet, c)
-87.4 (singlet, a), -90.6 (triplet, b).



Example 67

Eighty grams of acetaldehyde diethyl acetal were fluorinated in 20 hour reaction using a fluorine flow rate of 250 cc/min. The hydrocarbon was slowly pumped into a reactor containing 1.5 liters $(\text{CF}_2\text{Cl})_2\text{CFOCF}_2\text{OCF}(\text{CF}_2\text{Cl})_2$ and 400g sodium fluoride. The product, was obtained in a 45% yield and in 98% purity after distillation.

25 ^{19}F NMR (84.87 MHz, CFCl_3) -86.7 (multiplet, d),
-87.5 (singlet, a), -88.1 (multiplet, b), -97.0 (pentet, c).

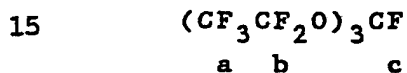


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Example 68

Eighty grams of triethyl orthoformate were fluorinated in a 4-liter stirred tank reactor containing 1.5 liters $(CF_2Cl)_2CFOCF_2OCF(CF_2Cl)_2$ and 400g sodium fluoride powder. The triethyl orthoformate, diluted with 200ml $(CF_2Cl)_2CFOCF_2OCF(CF_2Cl)_2$ was pumped into the reactor over an 18 hour period. Fluorination of the fluid at 10°C with 30% fluorine gave a 55% yield of a product having a boiling point of 92.5°C. The product was obtained in greater than 99% purity following an atmospheric distillation.

^{19}F NMR (84.87 MHz, CFC_2Cl_3) -52.2 (septet, c), -87.6 (singlet, a) -90.7 (doublet, b).

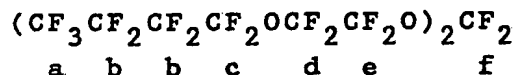
Example 69

A mixture of 3,612g butoxyethanol (30.6 moles), 261g paraformaldehyde (8.7 moles), 5g ion exchange resin and 350ml toluene was stirred at reflux as the water formed in the reaction was continuously removed. After 5 hours, the reaction was complete and a nearly quantitative yield of bis(2-butoxyethoxy)methane, bp 100-110°C at 0.5 Torr, was recovered. 915g of bis(2-butoxyethoxy)methane was diluted to a volume of 1700ml with 1,1,2-trichlorotrifluoroethane and pumped into a 5 liter reactor containing 5.7 liters of 1,1,2-trichlorotrifluoro-

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ethane. The reaction, which was carried out at 23°C, was complete in approximately 72 hours. The product, perfluorobis(2-butoxyethoxy)methane was obtained in 62% yield.

- 5 ^{19}F NMR (δ ppm vs CFCl_3) -51.7 (f), -81.6 (a), -83.4 c), -88.7 (e), -90.5 (d), -126.5 (b)



Example 70

- 10 A 4 liter stirred reactor was charged with 2 liters Fluorinert FC-75 (3M Corporation; mixture of perfluoro(2-n-butyltetrahydrofuran) and perfluoro(2-n-propyltetrahydropyran)) and heated to 70°C. Eighty grams of bis(2-butoxyethoxy)methane
- 15 was pumped into the reactor neat over an 18 hour period. The product, perfluorobis(2-butoxyethoxy)-methane, was recovered in 41% yield following an atmospheric distillation (b.p. 178°C). The ^{19}F NMR was identical to that obtained when the product was
- 20 prepared in 1,1,2-trichlorotrifluoroethane as the fluorination solvent (previous example).

Equivalents

- Those skilled in the art will recognize or be able to ascertain using no more than routine
- 25 experimentation many equivalents to the specific embodiments of the invention described herein. Such equivalents are intended to be encompassed by the following claims.

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CLAIMS

1. A method for liquid-phase fluorination,
comprising:
 - 5 a. introducing a hydrogen-containing compound
into a liquid, perfluorocarbon, perhalo-
genated chlorofluorocarbon or
chlorofluoroether medium while agitating
the medium so that the hydrogen-containing
10 compound is dissolved or dispersed within
the liquid medium;
 - 15 b. introducing a mixture of fluorine gas and
a diluent gas into the medium to
fluorinate the hydrogen-containing
compound, the fluorine being diluted so
15 that the liquid perfluorocarbon,
perhalogenated chlorofluorocarbon or
chlorofluoroether medium and fluorine in
the vapor space do not form a flammable
mixture, the amount of fluorine gas being
20 in excess of the stoichiometric amount
needed to replace all of the hydrogen
atoms of the hydrogen-containing compound
with fluorine; and
 - 25 c. continuing the fluorination until the
hydrogen-containing compound is fluori-
nated.
2. A method of Claim 1, wherein the hydrogen-
containing compound is an ether or polyether
having 5 to 10,000 carbon atoms.

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3. A method of Claim 2, wherein the ether is a linear polyether.
4. A method of Claim 1, wherein the hydrogen-containing compound contains at least one
5 carboxylic acid derivative.
5. A method of Claim 4, wherein the hydrogen-containing compound contains an acid chloride, acid fluoride or ester group.
6. A method of Claim 1, wherein the hydrogen-containing compound contains a sulfonic acid
10 derivative.
7. A method of Claim 6, wherein the hydrogen-containing compound contains a sulfonyl
15 chloride, sulfonyl fluoride or alkyl sulfonate group.
8. A method of Claim 1, wherein the hydrogen-containing compound is a mono or polycyclic aromatic compound having 6 to 30 carbon atoms.
9. A method of Claim 1, wherein the hydrogen-containing compound is a hydrocarbon polymer
20 having 10 to 10,000 carbon atoms.

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10. A method of Claim 1, wherein the hydrogen-containing compound is a cyclic ether having more than 10 carbon atoms.
- 5 11. A method of Claim 1, wherein the perhalogenated chlorofluorocarbon is 1,1,2-trichlorotrifluoroethane.
12. A method of Claim 1, wherein the perhalogenated chlorofluoroether is a perhalogenated chlorofluoropolyether.
- 10 13. A method of Claim 12, wherein the perhalogenated chlorofluoropolyether is:
- $$(\text{CF}_2\text{Cl})_2\text{CFOCF}_2\text{OCF}(\text{CF}_2\text{Cl})_2.$$
14. A method of Claim 12, wherein the perhalogenated chlorofluoropolyether is:
- 15
$$\text{CF}_2\text{ClCF}_2\text{OCF}_2\text{OCF}_2\text{CF}_2\text{Cl}.$$
15. A method of Claim 1, wherein the liquid medium is the fluorinated product.
16. A method of Claim 1, wherein the hydrogen-containing compound is first dissolved in a solvent and introduced into the liquid medium in solution.
- 20 17. A method of Claim 16, wherein the solvent has a high solvating power and does not consume fluorine.

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18. A method of Claim 16, wherein the solvent is the same liquid as the liquid medium.
19. A method of Claim 1, wherein the hydrogen-containing compound is insoluble in the liquid fluorination medium and is introduced into the medium to form a suspension or emulsion.
20. A method of Claim 19, wherein the emulsion or suspension is formed continuously in the reactor as the fluorination reaction proceeds.
21. A method of Claim 1, wherein the fluorination is carried out at a temperature of from about -40°C to about 150°C.
22. A method of Claim 21, wherein the fluorination is carried out at a temperature of about -10°C to about 50°C.
23. A method of Claim 1, wherein the fluorination is carried out in the presence of a hydrogen fluoride scavenger.
24. A method of Claim 23, wherein the hydrogen fluoride scavenger is sodium fluoride.
25. A method of Claim 1, wherein the fluorination is carried out in a batch or continuous mode.

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26. A method of Claim 1, wherein the gaseous products of the fluorination are circulated through a bed containing a hydrogen fluoride scavenger and then are reintroduced back into the fluorination reactor.
27. A method of Claim 26, wherein the hydrogen scavenger is sodium fluoride.
28. A method of Claim 1, wherein the hydrogen-containing compound is slowly extracted with liquid perhalogenated chlorofluorocarbon or chlorofluoroether medium wherein the extracted hydrogen-containing compound is then fluorinated.
29. A method of Claim 28, wherein the hydrogen-containing compound is phenanthrene.

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30. A method for liquid phase fluorination, comprising:
- a. providing a fluorination reactor wherein the reactor comprises a reaction vessel having a means for agitating a liquid contained therein; a means for introducing a hydrogen-containing compound into the reactor; means for introducing a gas into the reactor; means for removing a vaporized liquid from the reaction vessel operatively linked to a means for condensing the vaporized liquid; and a liquid return line operatively linked downstream from the condensing means wherein condensed liquid is returned to the reaction vessel;
 - b. placing a liquid perfluorocarbon, perhalogenated chlorofluorocarbon or chlorofluoroether medium in the reaction vessel;
 - c. introducing a hydrogen-containing compound into the reaction vessel while agitating the liquid medium so that the hydrogen-containing compound is dispersed within the liquid medium;
 - d. introducing fluorine gas diluted with an inert gas into the reaction vessel to fluorinate the hydrogen-containing compound, the fluorine being diluted so that the liquid perfluorocarbon perhalogenated chlorofluorocarbon or chlorofluoroether medium and fluorine in the vapor space do

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- not form a flammable mixture, the amount of fluorine gas being in excess of the stoichiometric amount necessary to replace all of the hydrogen atoms in the hydrogen-containing compound; and
- 5 e. continuing the fluorination reaction until the hydrogen-containing compound is perfluorinated.
- 10 31. A method of Claim 30, wherein the hydrogen-containing compound is an ether or polyether having 5 to 10,000 carbon atoms.
32. A method of Claim 31, wherein the ether is a linear polyether.
- 15 33. A method of Claim 30, wherein the hydrogen-containing compound contains at least one carboxylic acid derivative.
34. A method of Claim 33, wherein the hydrogen-containing compound contains an acid chloride, acid fluoride or ester group.
- 20 35. A method of Claim 30, wherein the hydrogen-containing compound contains a sulfonic acid derivative.
- 25 36. A method of Claim 35, wherein the hydrogen-containing compound contains a sulfonyl chlorid , sulf nyl fluoride r alkyl sulfonate group.

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37. A method of Claim 30, wherein the hydrogen-containing compound is a mono or polycyclic aromatic compound having 6 to 30 carbon atoms.
- 5 38. A method of Claim 30, wherein the hydrogen-containing compound is a hydrocarbon polymer having 10 to 10,000 carbon atoms.
39. A method of Claim 30, wherein the hydrogen-containing compound is a cyclic ether having more than 10 carbon atoms.
- 10 40. A method of Claim 30, wherein the perhalogenated, chlorofluorocarbon is 1,1,2-trichlorotrifluoroethane.
- 15 41. A method of Claim 30, wherein the perhalogenated chlorofluoroether is a perhalogenated chlorofluoropolyether.
42. A method of Claim 41, wherein the perhalogenated chlorofluoropolyether is:
- $$(\text{CF}_2\text{Cl})_2\text{CFOCF}_2\text{OCF}(\text{CF}_2\text{Cl})_2.$$
- 20 43. A method of Claim 41, wherein the perhalogenated chlorofluoropolyether is:
- $$\text{CF}_2\text{ClCF}_2\text{OCF}_2\text{OCF}_2\text{CF}_2\text{Cl}.$$
44. A method of Claim 30, wherein the liquid medium is the fluorinated product.

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45. A method of Claim 30, wherein the hydrogen-containing compound is first dissolved in a solvent and introduced into the liquid medium in solution.
- 5 46. A method of Claim 45, wherein the solvent has a high solvating power and does not consume fluorine.
47. A method of Claim 45, wherein the solvent is the same liquid as the liquid medium.
- 10 48. A method of Claim 30, wherein the hydrogen-containing compound is insoluble in the liquid fluorination medium and is introduced into the medium to form a suspension or emulsion.
- 15 49. A method of Claim 48 wherein the emulsion or suspension is formed continuously in the reactor as the fluorination reaction proceeds.
50. A method of Claim 30, wherein the fluorination is carried out at a temperature of from about -30°C to about 150°C.
- 20 51. A method of Claim 50, wherein the fluorination is carried out at a temperature of about -10°C to about 50°C.
- 25 52. A method of Claim 30, wherein the fluorination is carried out in the presence of a hydrogen fluoride scavenger.

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53. A method of Claim 52, wherein the hydrogen fluoride scavenger is sodium fluoride.
54. A method of Claim 53, wherein the fluorination is carried out in a batch or continuous mode.
- 5 55. A method of Claim 30, wherein the gaseous products of the fluorination are circulated through a bed containing a hydrogen fluoride scavenger and then are reintroduced back into the fluorination reactor.
- 10 56. A method of Claim 55, wherein the hydrogen scavenger is sodium fluoride.
57. A method of Claim 30, wherein the hydrogen-containing compound is slowly extracted with liquid perhalogenated chlorofluorocarbon or
15 chlorofluoroether medium wherein the extracted hydrogen-containing compound is introduced into the reaction vessel.
58. A method of Claim 57, wherein the hydrogen-containing compound is phenanthrene.

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59. A method for liquid-phase fluorination,
comprising:

- 05 a. introducing a hydrogen-containing compound
into a liquid, perfluorocarbon, perhalo-
genated chlorofluorocarbon or chloro-
fluoroether medium while agitating the
medium so that the hydrogen-containing
compound is dissolved or dispersed within
the liquid medium;
- 10 b. introducing mixture of fluorine gas and a
diluent gas into the medium to fluorinate
the hydrogen-containing compound, the
fluorine being diluted so that the liquid
perfluorocarbon, perhalogenated chloro-
15 fluorocarbon or chlorofluoroether medium
and fluorine in the vapor space do not
form a flammable mixture, the amount of
fluorine gas being in excess of the
stoichiometric amount necessary to replace
20 all of the hydrogen atoms in the hydrogen-
containing compound, the fluorine con-
centration of the gas mixture being about
10% to about 40%;
- 25 c. maintaining the fluorination reaction at a
temperature of from about -40°C to about
150°C;
- d. contacting the during the fluorination
hydrogen-containing compound with a
hydrogen fluoride scavenger, the amount of
30 hydrogen fluoride scavenger in relation to

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- the hydrogen-containing compound being sufficient to react with the hydrogen fluoride formed during fluorination; and
- 05 e. continuing the fluorination until the hydrogen-containing compound is fluorinated.
60. A method of Claim 59, wherein the fluorination reaction is carried out in the absence of a hydrogen fluoride scavenger at a temperature
- 10 below the boiling point of the liquid medium but sufficiently high to allow by-product hydrogen fluoride to be removed from the reactor.

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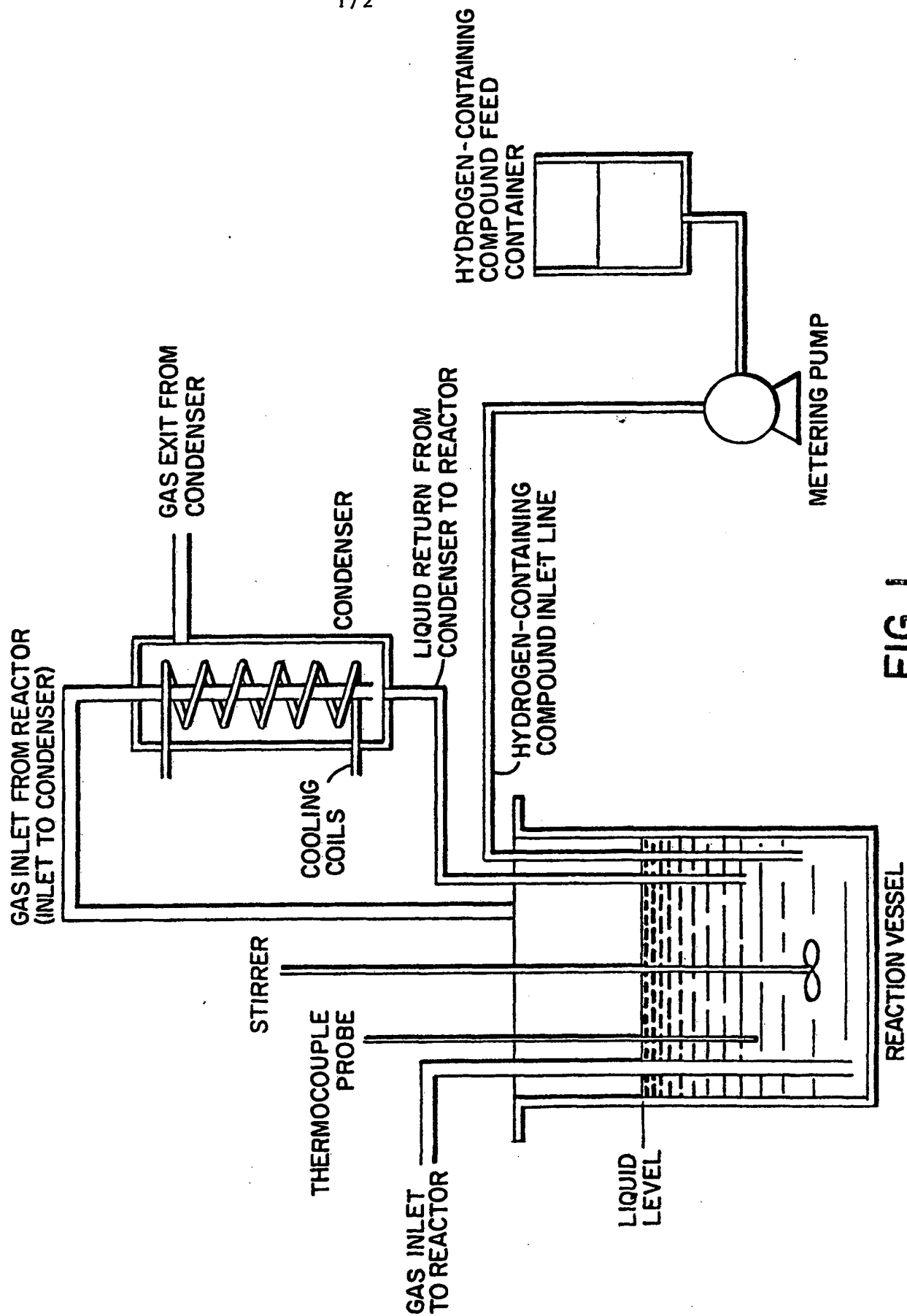


FIG. 1

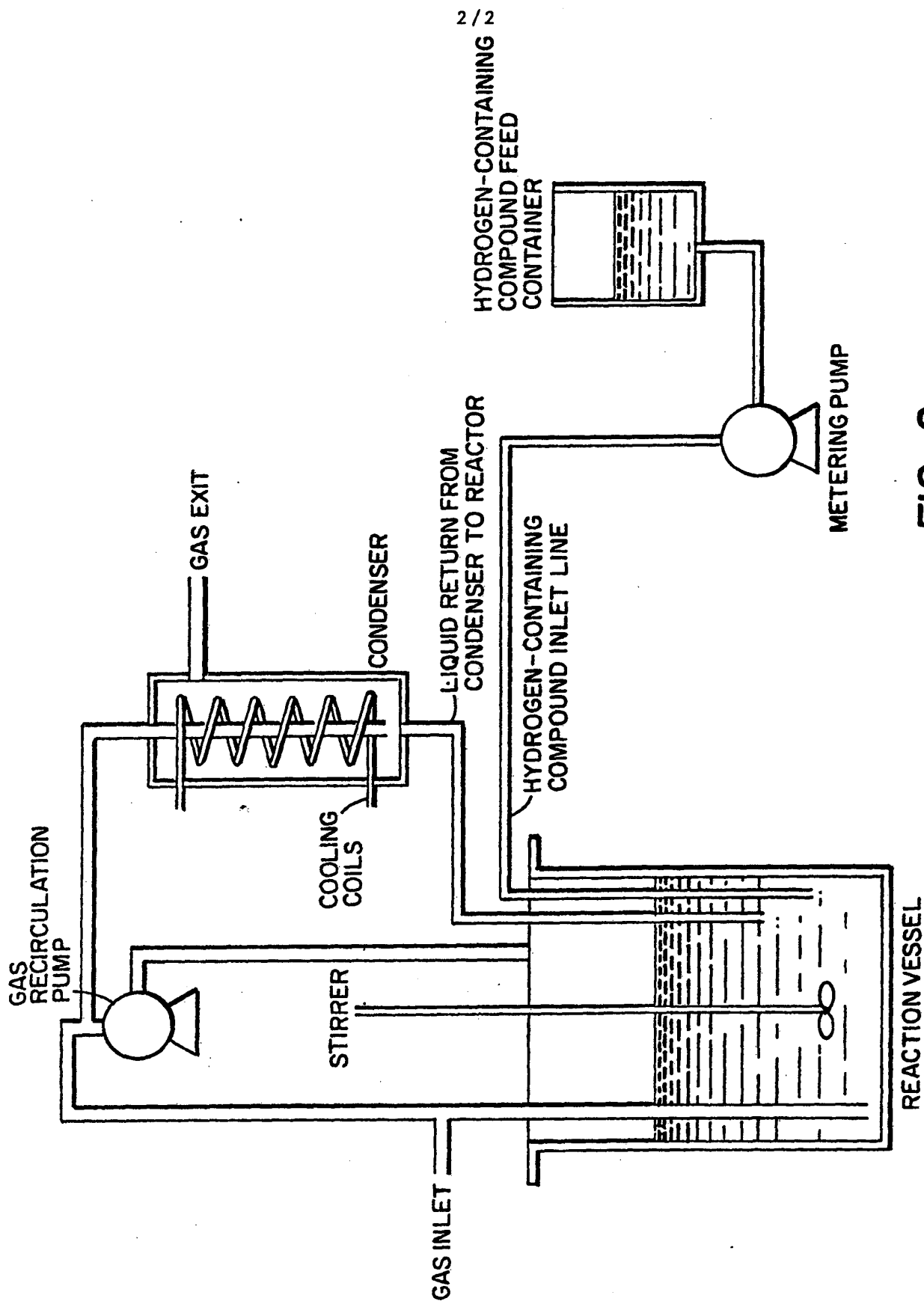


FIG. 2

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US 89/04251

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) * According to International Patent Classification (IPC) or to both National Classification and IPC IPC5: C 07 B 39/00, C 07 C 17/10, C 08 G 17/10																	
II. FIELDS SEARCHED <div style="text-align: center; border-top: 1px solid black; border-bottom: 1px solid black;">Minimum Documentation Searched †</div> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%; border-bottom: 1px solid black;">Classification System ‡</td> <td style="width: 50%; border-bottom: 1px solid black;">Classification Symbols</td> </tr> <tr> <td style="height: 40px; vertical-align: top; border-right: 1px solid black;">IPC5</td> <td>C 07 B; C 07 C; C 08 G</td> </tr> </table> <div style="text-align: center; border-top: 1px solid black; border-bottom: 1px solid black;">Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ‡</div>			Classification System ‡	Classification Symbols	IPC5	C 07 B; C 07 C; C 08 G											
Classification System ‡	Classification Symbols																
IPC5	C 07 B; C 07 C; C 08 G																
III. DOCUMENTS CONSIDERED TO BE RELEVANT* <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 10%;">Category *</th> <th style="width: 70%;">Citation of Document, †† with indication, where appropriate, of the relevant passages ‡‡</th> <th style="width: 20%;">Relevant to Claim No. ‡‡</th> </tr> </thead> <tbody> <tr> <td style="text-align: center; vertical-align: top;">Y</td> <td>EP, A1, 0018606 (DAIKIN KOGYO CO., LTD.) 12 November 1980, see especially p. 4-5 <div style="text-align: center;">--</div></td> <td style="text-align: center; vertical-align: top;">2,11-31, 40-60</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">Y</td> <td>WO, A1, 87/02994 (EXFLUOR RESEARCH CORPORATION) 21 May 1987, see the whole document <div style="text-align: center;">--</div></td> <td style="text-align: center; vertical-align: top;">2,11-31, 40-60</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">X</td> <td>EP, A2, 0269029 (AUSIMONT S.P.A.) 1 June 1988, see the whole document</td> <td style="text-align: center; vertical-align: top;">1</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">Y</td> <td><div style="text-align: center;">--</div></td> <td style="text-align: center; vertical-align: top;">2,11-31, 40-60</td> </tr> </tbody> </table>			Category *	Citation of Document, †† with indication, where appropriate, of the relevant passages ‡‡	Relevant to Claim No. ‡‡	Y	EP, A1, 0018606 (DAIKIN KOGYO CO., LTD.) 12 November 1980, see especially p. 4-5 <div style="text-align: center;">--</div>	2,11-31, 40-60	Y	WO, A1, 87/02994 (EXFLUOR RESEARCH CORPORATION) 21 May 1987, see the whole document <div style="text-align: center;">--</div>	2,11-31, 40-60	X	EP, A2, 0269029 (AUSIMONT S.P.A.) 1 June 1988, see the whole document	1	Y	<div style="text-align: center;">--</div>	2,11-31, 40-60
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X	EP, A2, 0269029 (AUSIMONT S.P.A.) 1 June 1988, see the whole document	1															
Y	<div style="text-align: center;">--</div>	2,11-31, 40-60															
<table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%; vertical-align: top;"> * Special categories of cited documents: ‡‡ "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed </td> <td style="width: 50%; vertical-align: top;"> "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "Δ" document member of the same patent family </td> </tr> </table>			* Special categories of cited documents: ‡‡ "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "Δ" document member of the same patent family													
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IV. CERTIFICATION <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%; border-bottom: 1px solid black; vertical-align: bottom;"> Date of the Actual Completion of the International Search 8th December 1989 </td> <td style="width: 50%; border-bottom: 1px solid black; vertical-align: bottom;"> Date of Mailing of this International Search Report <div style="text-align: center; font-size: 1.2em;">10. 11 90</div> </td> </tr> <tr> <td style="border-bottom: 1px solid black; vertical-align: bottom;"> International Searching Authority <div style="text-align: center; font-weight: bold;">EUROPEAN PATENT OFFICE</div> </td> <td style="border-bottom: 1px solid black; vertical-align: bottom;"> Signature of Authorized Officer <div style="text-align: right; font-weight: bold;">T.K. WILLIS</div> </td> </tr> </table>			Date of the Actual Completion of the International Search 8th December 1989	Date of Mailing of this International Search Report <div style="text-align: center; font-size: 1.2em;">10. 11 90</div>	International Searching Authority <div style="text-align: center; font-weight: bold;">EUROPEAN PATENT OFFICE</div>	Signature of Authorized Officer <div style="text-align: right; font-weight: bold;">T.K. WILLIS</div>											
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III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	J. Org. Chem., Vol. 50, 1985, D. F. Persico et al.: "A General Synthesis for Symmetrical Highly Branched Perfluoro Ethers: A New Class of Oxygen Carriers ", see page 5156 - page 5159 --	1-29
A	J. Am. Chem. Soc., Vol. 107, 1985, D. F. Persico et al.: "Synthesis of Perfluoropolyethers via Hydrocarbon Polyesters: A New General Method", see page 1197 - page 1201 --	1-29
A	J. Org. Chem., Vol. 54, 1989, Wen-Huey Lin et al.: "Synthesis of Perfluorotetraalkyl Orthocarbonates Using Elemental Fluorine ", see page 1990 - page 1992 -----	1-29

**ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO. PCT/US 89/04251**

SA 31693

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on 08/11/89
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A1- 0018606	12/11/80	JP-A- 55145628	13/11/80
		US-A- 4524032	18/06/85
WO-A1- 87/02994	21/05/87	AU-D- 65965/86	02/06/87
		EP-A- 0245462	19/11/87
		JP-T- 63501297	19/05/88
		US-A- 4755567	05/07/88
EP-A2- 0269029	01/06/88	JP-A- 63211247	02/09/88

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